MERMAID

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1.2			

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1 Introduction

MERMAID activities are applied to four pilot study sites (Fig. 1.1) with different environmental characteristics:

- in the Baltic Sea, estuarine area;
- in the trans-boundary area of the North Sea-Wadden Sea, active morphology site;
- in the Atlantic Ocean, deep water site;
- in the Mediterranean Sea, sheltered deep water site.

This report presents the assessment of the hydrodynamic, environmental, social and risk conditions at the above listed study sites. It also proposes the preliminary design of the single and multi-purpose platform concepts in the sites, the overall aim being to provide the other WPs with all the necessary information to scope specific research activities for improving and updating the design.

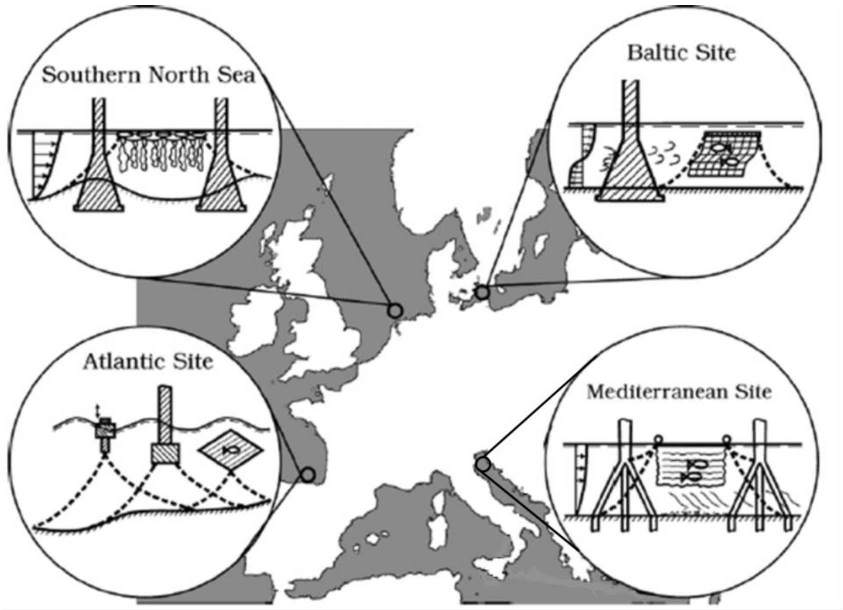

Fig. 1.1 Location of the four sites and scheme of design options.

Pilot study sites have been selected for their specific challenges, their being representative of different environmental, social and economic conditions as well as the availability of data and opportunity to link directly to local research teams, stakeholders, policy managers, SMEs and industrial networks. In this way, MERMAID gains immediate access to established groups of stakeholders who will be motivated to participate in the demonstration of the project deliverables. An overview of the main site characteristics is provided in Tab. 1.1.

A series of possible design options and industrial interaction will be scoped and implemented on a site by site basis. The extent and focus of this interaction will vary from site to site and will depend upon the existence and / or flexibility of policies and social. economic and environmental management schemes or constraints.

Tab. 1.1 Characteristics of Study sites

Site, Sea	**Environmental characteristics**	**Design type**	**Specific issues**
Krieger Flak, Estuarine site, Baltic sea	• cold brackish waters with optimum salinities for temperate fish • location on the pathway for exchange flow between Baltic proper and the North Sea • high wind energy potential	• gravity based turbine foundations • extensive mariculture	• Dredging • Mariculture spills • Sand mining in area
Krieger flaks, Estuarine site, Baltic sea	• cold brackish waters with optimum salinities for temperate fish • location on the pathway for exchange flow between Baltic proper and the North Sea • high wind energy potential	• gravity based turbine foundations • extensive mariculture	• Dredging • Mariculture spills
North Sea	• Waters with optimum salinities, temperate and nutrients for seaweed • Area where there is exchange of sediment between the North Sea and the Wadden Sea • high wind energy potential	• gravity based turbine foundations • extensive aquaculture	• Economic feasibility • Scour and backfilling processes • Environmental impact
Ubiarco and Santoña, Far Offshore area, Atlantic Ocean	• Very high wind energy potential • Very high wave energy potential	• floating platform (100 m depth) • multiple energy converters, i.e. wind and waves	• grid connections • mooring systems
Acqua Alta platform, Venice, Mediterranean Sea	• moderate wind energy potential • moderate wave energy potential	• gravity based foundations (16 m depth) • multiple energy converters, , i.e. wind and waves • gardening of macroalgae • fish farm	• Grid connections • Mooring systems • Environmental impact • Biodiversity • Economic feasibility

The structure of this document is as follows.

The detailed assessment of the environmental, social and economic conditions are reported for the Baltic Sea, North Sea, Atlantic Ocean and Mediterranean sites in Sections 2.1, 2.2, 2.3 and 2.4 respectively.

Section 3.1 outlines the design procedure at the sites and Sections 3.2, 3.3., 3.4 and 3.5 describe the suitability to the implementation of different functionalities and the preliminary design respectively in the Baltic Sea, North Sea, Atlantic Ocean and Mediterranean sites considering both single and multi-purpose concepts.

Section 4 synthesizes the most relevant characteristics of the sites and of the preliminary design by means of few standard format sheets specifically prepared to allow easier interaction with end users, in cooperation with WP 2.

Finally the preliminary design and the key features identified at each site are synthesized in Section 5.

2 Overview of conditions at the sites

2.1 The Estuarine site, Baltic Sea

2.1.1 Short site description

The Kriegers Flak is a large sandy shoal with a sand layer thickness of up to 8 m located in the Western Baltic Sea between Denmark, Sweden and Germany (Fig. 2.1.1). The name Flak actually refers to a wide shallow shoal in Danish. The central plain is located at 18-20 m depth gently sloping to more than 40 m to the N, E and S. The major part of the sandy plain is located within the Danish Economic Zone. In the shallow parts (18-23 m) the seabed consist of medium sand with a varying median grain size between 0.2 and 0.4 mm with some content of gravel and coarser fractions. Organic content (loss on ignition, LOI) is low at 0.1-0.15 % of sediment dry weight at the plain but increased to 3-5% at 40 m. Dedicated areas (about 20 km^2) within the Danish part are extensively used for sand extraction.

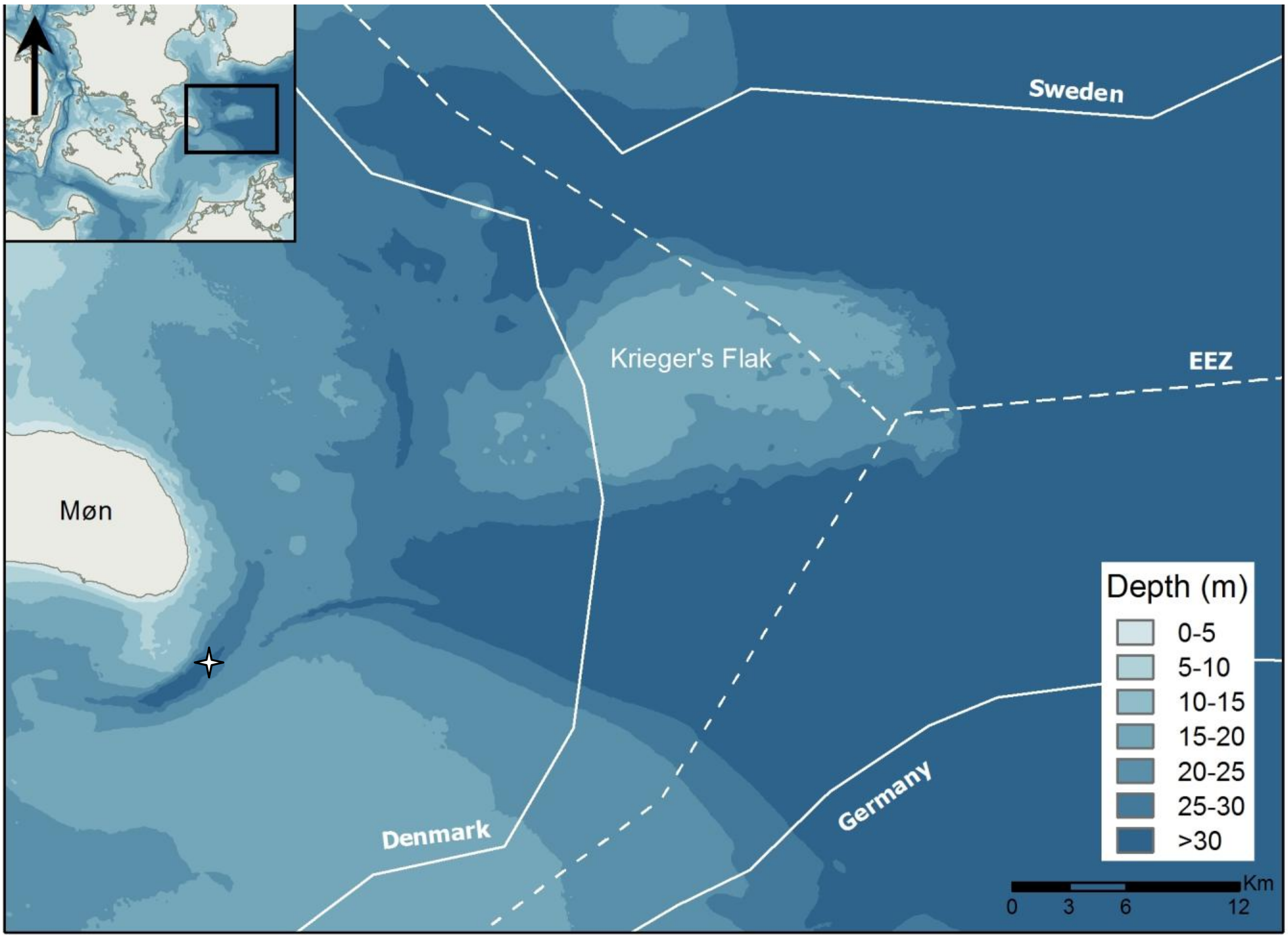

Figure 2.1.1 - Location of Kriegers Flak depicting territorial and EEZ of Denmark, Sweden and Germany. Star symbol show location of monitoring station for water quality.

2.1.2 Current policy, management and planning strategies

Kriegers Flak has already been selected and approved by the Danish parliament as the next large offshore wind farm (600 MW) expected to be in operation in 2020. Parallel with the Danish preparations, Germany plans for a similar sized wind farm on Kriegers Flak (within German EEZ) and mutual plans for a common network. For the sake of a timely EIA process a preliminary Technical Project Description for the Danish wind farm has been drafted in 6th May 2013 (Dokument nr. 37007/13, sag 12/497).

In Denmark, aquaculture is regulated as an integrated part of the Danish fisheries sector and as such it is mainly covered by the Fisheries Act under the Ministry of Food, Agriculture en Fisheries. The overarching legal framework for marine farming is the Water Framework Directive, implemented in Danish legislation as consolidated act. No. 932 issued April 24th 2009. Marine farming is only partly covered by this directive. The ecological status applies for coastal waters up to 1 nautical mile whereas the chemical status applies for coastal waters up to 12 nautical miles. The most critical issue in this directive is the discharge of nitrogen that must not been increased making it impossible for farms to increase the production without an increase of nitrogen load. If marine farmers want to increase their production they can apply for a part of the total nitrogen quota. But the permit is only granted under the condition that the increase in the discharge of nitrogen is eliminated by compensatory farming e.g. by farming of macroalgae. However, it is not clear if the compensation should eliminate the discharge of nitrogen fully or only partly. It is still being discussed. At present, no offshore aquaculture farms do exist in Danish EEZ and practices how to administer offshore aquaculture production have not been developed.

Legislation and Policies on Aqua-Culture

According to the Danish Aquaculture Organisation (2012), the environmental legislation on aquaculture exists on two levels: (1) general legal acts that all types of economic activity have to comply with and (2) legal acts for various form of aquaculture.

There is no specific law on aquaculture in Denmark. Danish aquaculture is strictly regulated by environmental rules, with the exception of full recirculation eel farms, all Danish fish farms have to be officially approved in accordance with the Danish Environmental Protection Act Ord. n0. 122 of March 1st 1991 (Danish Aquaculture Organisation, 2012).A fixed feed quota is assigned to each individual farm in addition to specific requirements including feed conversion ratios, water use and treatment, effluents, removal of waste and offal, etc. In Denmark, aquaculture is being an integrated part of the Danish fisheries sector and as such it is mainly covered by the Fisheries Act under the Ministry of Food, Agriculture en Fisheries.

The overarching legal framework for marine farming is the environmental frame directive, implemented in Danish legislation as consolidated act. No. 932 issued April 24th 2009 (Danish Aquaculture Organisation, 2012). Marine farming is only partly covered by this directive. The ecological status applies for coastal waters up to 1 nautical mile whereas the chemical status applies for coastal waters up to 12 nautical miles. The most critical issue in this directive is the discharge of nitrogen. In the programme of measures for marine farming stands that there must be no overall reduction in the current discharge of nitrogen approved marine farms, but also that new permits must not lead to increased discharge. It is impossible for farms to increase the production without an increase of nitrogen load. On the longer term farms could possible compensate for such increase. If marine farms want to increase their production it can apply for a part of the total nitrogen quota. But the permit is only granted under the condition that the increase in the discharge of nitrogen is

eliminated by compensatory farming. However, it is not clear if the compensation should eliminate the discharge of nitrogen fully or only partly. It is still being discussed.
The management, control and development of fisheries and aquatic resources, like aquaculture, in Denmark are regulated by the Fisheries act (2004) (http://www.fao.org/fishery/legalframework/nalo_denmark/en). Chapter 13 of this act addresses offshore ocean farming and establishes a licensing system governing the of mariculture facilities. Besides the fisheries act, the regulation on the establishment and operation of ocean farms contains more detailed rules on the licensing system of mariculture facilities. There is no general definition of aquaculture in the Fisheries Act (2004) http://www.fao.org/fishery/legalframework/nalo_denmark/en. The Regulation relative to the establishment and operation of ocean farms (1991), adopted under the Act, has, however, the following definition of ocean farming: "With ocean farming is understood fish farms consisting of cages and the like, placed in marine waters which requires the use of feed for its operation".
However, for aquaculture facilities that are placed on land taking in marine water and for fish farming of mussels, oysters etc. no regulations have been issued pursuant to the Fisheries act (2004) (http://www.fao.org/fishery/legalframework/nalo_denmark/en concerning licensing). For fish farming that requires feed an approval according to the Environmental Act is required.
The authorities and the set of regulations for farming marine fish in Denmark depend on a category to which a farm belongs. Three categories are defined (Pedersen, 2000)

- Category 1: land-based sea water farms. These are defined as land-based farms taking in or pumping in sea water, including cooling-water from e.g. power plants. The operation of the farm is dependent on the use of feed.
- Category 2: farms with net cages placed in sea water. These are defined as farms consisting of net cages, netted boxes or the like placed in marine waters. The operation of the farm is dependent on the use of feed.
- Category 3: Farms in seawater without the use of feed.

Helsinki Convention

The Helsinki convention has the central aim to protect the marine government of the Baltic Sea from all sources of pollution. The convention aims to prevent and eliminate pollution in order to restore the ecological damage in the Baltic Sea. The Helsinki commission (HELCOM) is the governing body of the convention. Helcom works to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental co-operation between Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. HELCOM works as (www.helcom.fi).

- an environmental policy maker for the Baltic Sea area by developing common environmental objectives and actions;
- an environmental focal point providing information about (i) the state of/trends in the marine environment; (ii) the efficiency of measures to protect it and (iii) common initiatives and positions which can form the basis for decision-making in other international fora;
- a body for developing, according to the specific needs of the Baltic Sea, Recommendations of its own and Recommendations supplementary to measures imposed by other international organizations;
- a supervisory body dedicated to ensuring that HELCOM environmental standards are fully implemented by all parties throughout the Baltic Sea and its catchment area; and a coordinating body, ascertaining multilateral response in case of major maritime incidents.

The Commission unanimously adopts recommendations for the protection of the marine environment, which the governments of the contracting parties must act on in their respective national programs and legislation.

Spatial policy

According to the act relative to planning, regional plans that are prepared by regional counties are important documents. The plans include guidelines for the use of water ways, lakes and waters and accordingly establish aquaculture zones.

Permits and procedures

All marine farms must have an environmental permit no later than 2014. The Environmental Protection act (no. 1757 issued December 22th 2006) sets the overall framework for issuing such permits. At this time only a few marine farms have permits under this act (The Danish Aquaculture Organisation, 2012).

Marine farms also have to comply with the requirements for discharge of residues of medicines (Order no. 1022 issues August 25th 2010) and protected habitats (Protection of Nature Act no. 933 issued September 24th 2009), The Danish Aquaculture Organisation (2012).

For development of aqua culture activities an Environmental Impact Assessment (EIA) is necessary. These are found in the Planning act (order number 1510 issued December 15th 2010). For marine farms situated up to one nautical mile for the coast will require a full EIA. This is a general rule. To some extent it is decided by the local government in the area and they can administer this rule in different ways. For farms outside the nautical mile zone only a screening is required. This has been done as a result of a political compromise between government, farmers and environmental organizations.

The regulation on supplementary rules contains requirements regarding the contents of the EIA. The Regulation provide that when establishing a new marine water fish farm outside a zone designated for aquaculture in the Regional Plan, or when changing such a facility considerably, an EIA shall be worked out. If the aquaculture facility in question is designated for intensive fish farming or has an intake of fresh water, an EIA shall be worked out as far as the facility it is likely to have a considerable impact on the environment, even when it is to be established in an aquaculture zone. The Regulation lists the different criteria that shall be used when considering whether a facility is likely to have such an impact, i.e. the size of the facility, waste production, the vulnerability of the surrounding environment etc. When it comes to the contents of the EIA, the Regulation states that the EIA shall include a description of the planned facility, a summary of the most important alternative sites that has been examined, the reasons for the choice of alternatives, a description of the environment that can be considerably influenced by facility, as well as an account of the short term and long term influence on the environment. As to ocean farms outside the County Council planning area, the Coastal Directorate decides whether an EIA shall be carried out in relation with an application for the setting up of a facility (http://www.fao.org/fishery/legalframework/nalo_denmark/en).

A permit must be obtained before establishing or extending a farm. Quite lot information is required according to a set of regulations for polluting industries. Pedersen (2000) describes the stages before an application can be approved (see Fig. 2.1.2)

Fig. 2.1.2 Application procedures for approval of landbased sea water farms

Procedures category 2: Farms with net cages placed in sea water
For these kinds of farms an application must be submitted to the regional county and the Directorate of Fisheries, who are both competent authorities able to issue a permit (see Fig. 2.1.3)

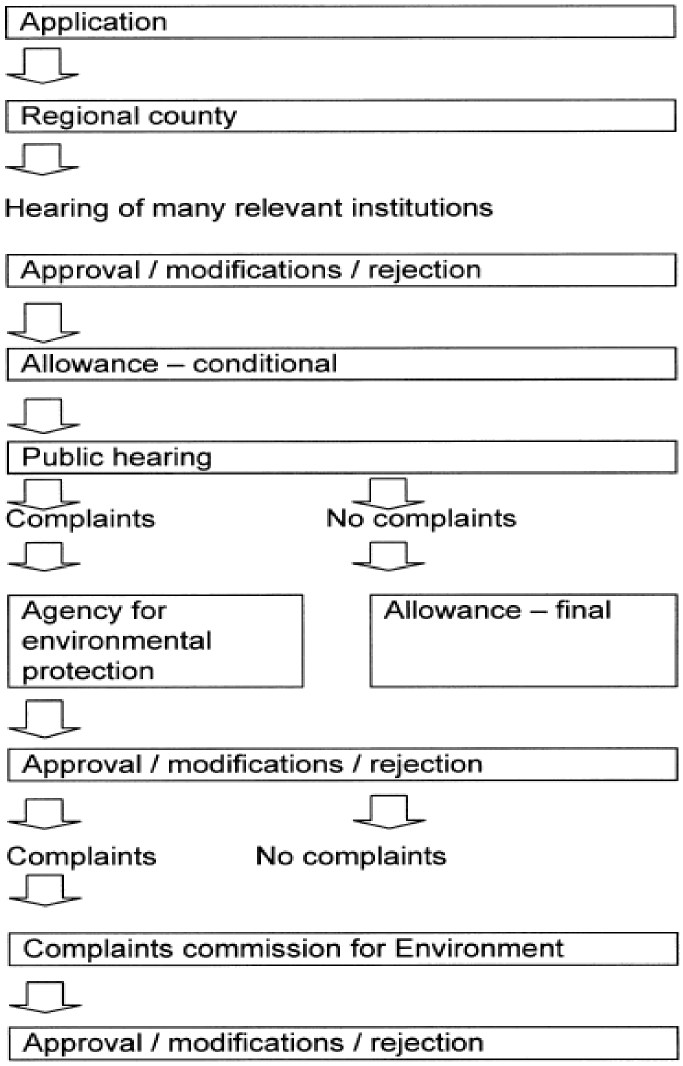

Fig. 2.1.3 Application procedures for approval of farms with net cages placed in sea water

Procedures category 3: Farms in seawater without the use of feed
The authority that is able to approve an application for category 3 farms is the Fisheries Directorate. They collect statements about the environmental form the county and the Royal Danish Directorate of Navigation and Hydrography before issuing a license (see Fig. 2.1.4)

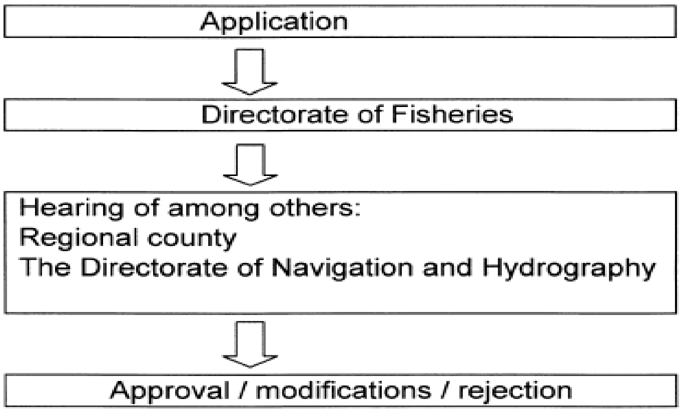

Fig. 2.1.4 Application procedures for approval of farms in seawater without the use of feed

Legislation and Policies Off Shore Wind Energy

Denmark has a long tradition on energy policy. When oil prices accelerated in 1973 Denmark was among the OECD countries which were most dependent on oil in its energy supply (Danish Energy Agency, 2012). After the oil crises Denmark launched an active energy policy to ensure the security of supply of energy and to reduce its dependency on imported oil.
Denmark chose early on to prioritise energy savings and a diversified energy supply that concentrate on increased use of renewable energy. A broad array of notable energy-policy initiatives were launched, including a focus on combined electricity and heat production, municipal heat planning and on establishing a more or less nation-wide natural gas grid. Furthermore, Denmark extensively improved efficiency of the building mass, and launched support for renewable energy, research and development of new environmentally friendly energy technologies as well as ambitious use of green taxes (Danish Energy Agency, 2012).
Development and implementation of wind energy have been included in all Danish energy strategies. Policy instruments – such as taxation, production subsidies, local ownership, agreements with utilities, regulation on grid connection and spatial planning procedure and technology-push policy instruments, such as R&D programmes, test station for wind turbines as well as approval and certification schemes, have been tools in the strategies. According the Danish Energy Agency, the most important incentive to promote wind turbines were an obligation for the Danish Transmission System Operator (TSO) and the consumers to buy renewable electricity at a fixed price (Ryland, 2010).

Legislation on off-shore wind parks

In the Promotion of Renewable Energy Act (Act no 1392 27th December 2008) and the Danish Electricity Act, the Danish Government gives the main conditions for offshore wind parks (Danish Energy Policy, 2012). Chapter 3 is mainly relevant for off-shore wind parks. That chapter regulates the access to exploiting energy from water and wind offshore. Most import condition is that the

right to exploit energy from water and wind within the territorial waters and the exclusive economic zone (up to 200 nautical miles) around Denmark belongs to the Danish State. The act also lays down the procedures for the approval of electricity production from water and wind and pre-investigation. Permission will be given for a specific area.
Important sections of the Renewable Energy act (2008) (Danish Energy Agency, 2012):

- Approval for preliminary investigations shall be granted either after an invitation for applications in a tendering procedure or after receipt of an application.
- Approval for preliminary investigations shall be granted for areas in which the Minister for Climate and Energy considers energy exploitation may be relevant. Approval shall be granted as an exclusive right for a specified area and time period.
- The Minister for Climate and Energy may stipulate terms for the approval, including on the conditions to be investigated, on reporting, on the performance and results of the preliminary investigation, on the access of the Minister to utilise the results of the preliminary investigation, cf. and on compliance with environmental and safety requirements and similar.

Permits and procedures

For development and establish of offshore wind park projects in Denmark, three licences are required. All licences are granted by the Danish Energy Agency (Danish Energy Agency, 2012):

1. License to carry out preliminary investigations
2. Licence to establish the offshore wind turbines (only given if preliminary investigations show that the project is compatible with the relevant interests at sea)
3. Licence to exploit wind power for a given number of years, and – in the case of wind farms of more than 25 MW – an approval for electricity production. (given if conditions in licence to establish project are kept)

When the project can be expected to have an environmental impact, an Environmental Impact Assessment (EIA) must be carried out. The specific procedure for the Environmental Impact Assessment (EIA) regarding offshore electricity producing installations is described in Executive Order No. 684 of 23 June 2011 on EIA. That also includes sections that implement the EU EIA directive (PM). In general, an Environmental Impact Assessment (EIA) report must be prepared before an application to set up an offshore wind farm can be processed (Danish Energy Agency, 2012).
The rules governing EIA reports are described in Executive Order no. 684 of 23 June 2011. Any party applying to establish an offshore wind farm must prepare an environmental report in order to ensure:

- That the environmental conditions within the defined installation are described,
- That impact and reference areas are studied and described,
- That all known environmental impacts in connection with the establishment and operation of the wind turbine installation have been previously considered and assessed, and
- That the authorities and the general public have a basis for assessing and making a decision regarding the project.

When, on the basis of preliminary investigations (license 1) an application (including an EIA report) has been submitted regarding an offshore wind power project, the Danish Energy Authority present this material for public consultation with a deadline of at least eight weeks. After that the final authorisation for the establishment (license 2) of the offshore wind farm is done according to detailed conditions that reflect both the conclusions of the EIA report and consultation responses from the general public and the authorities concerned. The authorisation, issued by the Danish

Energy Authority, is made public. Any party with an interest in the decision has the right to register a complaint with the Energy Appeal Board regarding the decision's environmental aspects. The authorisation may not be acted upon before the appeal deadline has expired. Once authorised to carry out a project, the developer must provide the Danish Energy Authority with documentation proving how the conditions in the permit issued will be fulfilled. This must be done in the form of a detailed project description of the construction/installation works. The developer may not begin to construct the offshore wind farm until the Danish Energy Authority has determined that the documentation submitted is sufficient (Danish Energy Agency, 2012).

When an installation is ready to produce electricity for the grid, the holder of the authorisation for the establishment applies to the Danish Energy Authority for a permit to exploit the wind energy (license 3). Electricity production may not begin before such a permit has been issued. In addition, the developer must also obtain a licence to produce electricity if the overall project has a capacity of more than 25 MW and if the developer does not already hold such a licence (Danish Energy Agency, 2012).

In general, the establishment of offshore wind turbines can follow two different procedures: a government tender procedure run by the Danish Energy Agency; or an open-door procedure. For both procedures, the project developer requires all 3 licenses (Danish Energy Agency, 2012).In the open-door procedure; the project developer takes the initiative to establish an offshore wind farm of a chosen size in a specific area. In an open-door project, the developer pays for the transmission of the produced electricity to land. An open-door project cannot expect to obtain approval in the areas that are designated for offshore wind farms in the report Future Offshore Wind Power Sites – 2025 from April 2007 and the follow-up to this from September 2008. There are three examples of the open-door procedure. It was followed for the DONG Energy off-shore wind farm at Avedøre and Frederikshavn – and for the Sund&Bælt project at Sprogø.

In the government tender procedure, the Danish Energy Agency announces a tender for an offshore wind turbine project of a specific size, e.g. 200 MW, within a specifically defined geographical area. Often, a government tender is carried out to realise a political decision to establish a new offshore wind farm at the lowest possible cost. Depending on the nature of the project, the Danish Energy Agency invites applicants to submit a quotation for the price at which the bidders are willing to produce electricity in the form of a fixed feed-in tariff for a certain amount of produced electricity, calculated as number of full-load hours. The winning price will differ from project to project because the result of a tender depends on the project location, the wind conditions at the site, the competitive situation in the market at the time, etc. In projects covered by a government tender, Energinet.dk owns both the transformer station and the underwater cable that carries the electricity to land from the offshore wind farm.

2.1.3 Metocean conditions and renewable energy potential

Wind speed in the following is based on analysis of Envisat ASAR satellite data providing speeds at 10 m above sea level. The mean wind speed is shown in Fig. 2.1.5 .

Wind statistics as a wind rose and Weibull distribution is shown in Fig. 2.1.6. Winds are predominantly westerly during summer. Easterly winds are common during winter.

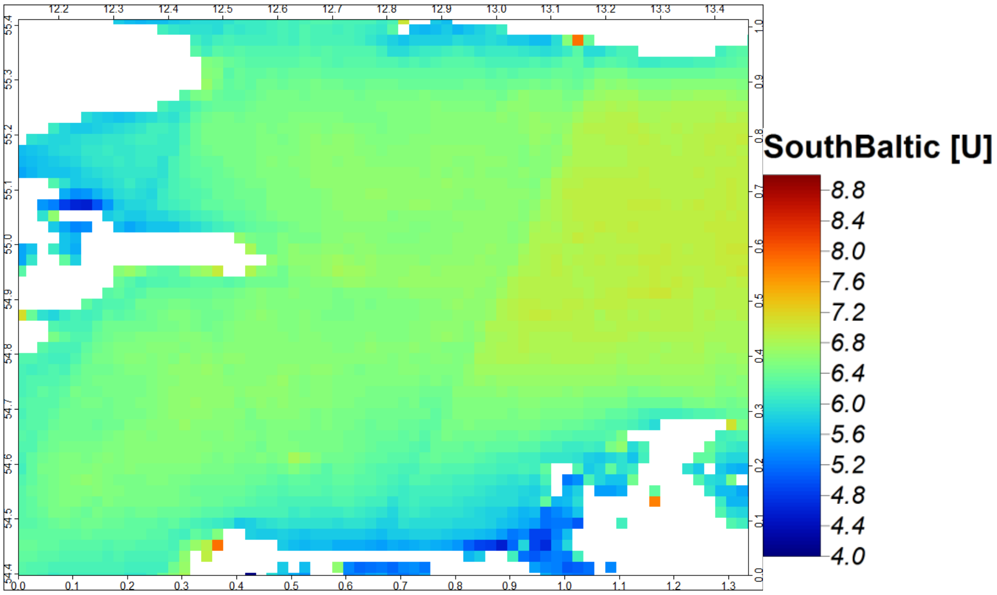

Fig 2.1.5 - Map of mean wind speed from Kriegers Flak based on Envisat ASAR wind fields.

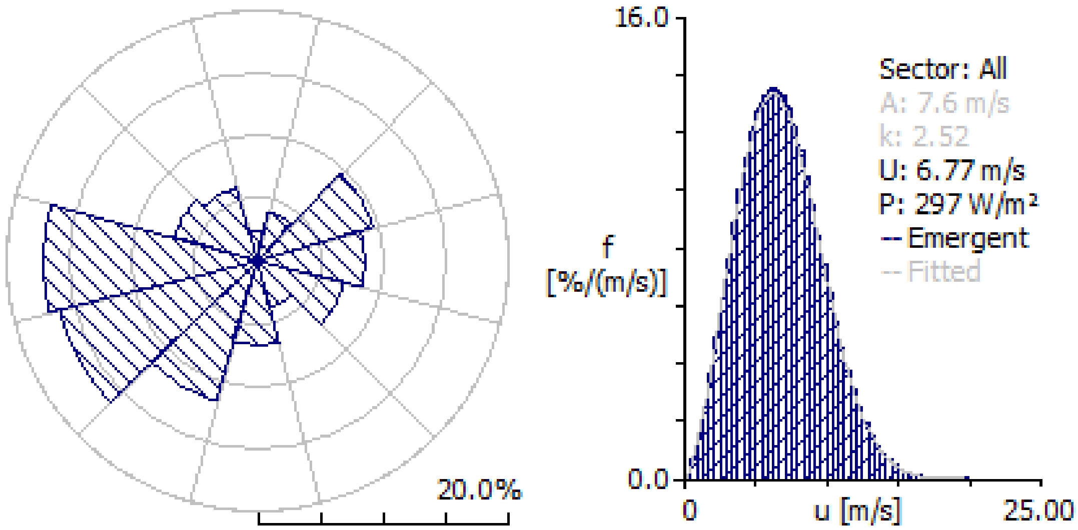

Figure 2.1.6 -. Wind rose and Weibull distribution at 10 m at 55.00°N 13.08°E in the South Baltic Sea observed from Envisat ASAR.

2.1.4 **Hydromorphological analysis**

Currents are very variable and driven by wind, horizontal density gradients and differences in sea level. Freshwater surplus in the Baltic Sea catchment gives rise to westerly annual mean currents of 2-5 cm/s in the Kriegers Flak area. Being located at the main entrance to the Baltic Sea there are ae dense bottom currentsw flowing easterly direction north and south of the shoal. Combined with the strong meteorologically induced variability, this gives rise to rapid salinity fluctuations within a

range from 8 PSU to 30 PSU. The inflow currents are of the order 20-30 cm/s. In general currents on the shoal are modest below 1 m/s.
The Southern Baltic Sea is basically tideless, but may experience storm surges up to about 1 m, in extreme cases 3.3 m during adverse meteorological conditions, where passing low pressure systems may induce a combined pumping of North Sea water into the Baltic and “sloshing” in the Baltic Basin (BSH, 2005)

Waves conditions are generally modest, but rough seas (waves larger than 2-3 m) are common in November-December (see Fig. 2.1.7 to 2.1.9). During May through August calm sea (< 0.5 m) are common. Swells are uncommon at Kriegers Flak. Significant wave heights are on long term average about 0.9 m. In extreme situations preliminary estimates of the significant wave heights are about 4.5 m (10 year return period), 5.2 m (50 year return period) and 5.5m (100 year return period) (Hanson and Larson, 2009. Estimated mean wave periods at KF are about 3.5 sec with peak periods up to 4.5 sec (Soomere and Räämet, 2011).
The seabed at Kriegers Flak in the area planned for the Danish offshore wind farm consist of medium to fine sand from Littorina deposits with median grain size between 0.2 and 0.4 mm and very low content of fines but some content of pebbles and stones. The seabed is relatively level with slopes below 0.3 %. The thickness of the sand shoal are typically 8 m.
Geologically the Kriegars Flak is considered stable, with very little erosion and active sediment transport (Energinet.dk, 2012)

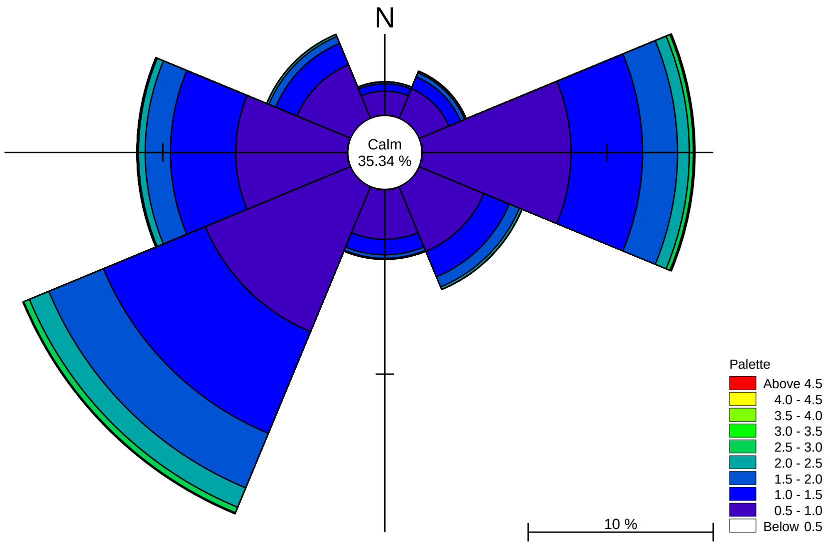

Figure 2.1.7 - Example of wave rose from Kriegers Flak

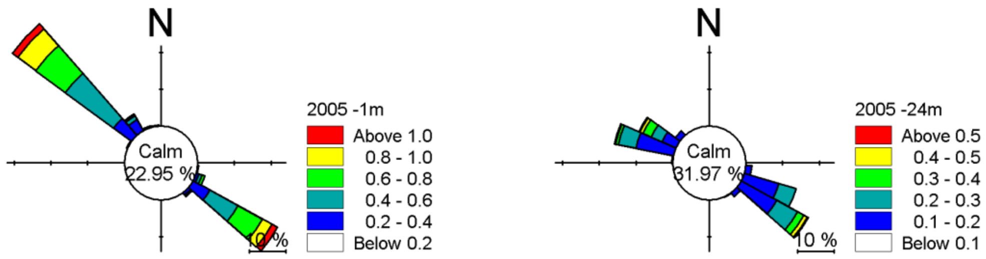

Figure 2.1.8 Example of current Rose, surface and bottom

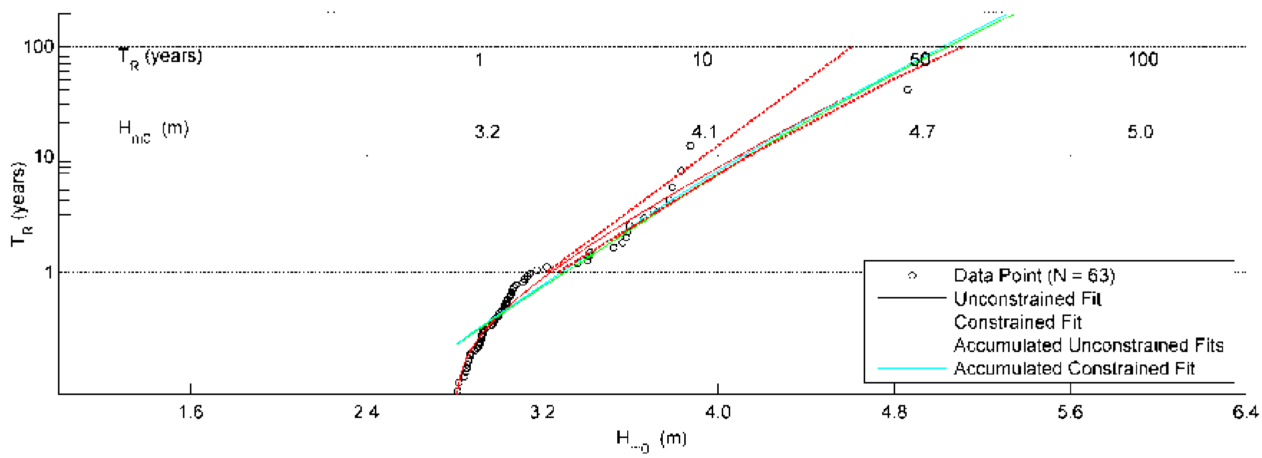

Figure 2.1.9 - Example of extreme wave statistics

2.1.5 Environmental characterization

Water Quality

Hydrographic and water quality data are available from a near-coastal station east of Møn sampled monthly during 1990-1997 under Danish Monitoring Programme (MADS) and recently (2009-2010) during an EIA study (DHI 2013). Additional data were collected in the Swedish sector of Kriegers Flak in 2002 and 2003 in connections with an Environmental Impact Assessment for a Wind Farm (SoW AB 2004).

Throughout the year salinity is stable at 7-9 PSU in the upper 15-18 m part of the water column. Density stratification occurs regularly during calm periods in summer and is reinforced by thermoclines located between 10 and 15 m. Surface water temperature varies seasonally between 0 and 20 °C. During summer and early autumn bottom water oxygen becomes under-saturated, if stable density stratification is established but concentration rarely decreases to below 2-3 mg/l. During winter, spring and early summer concentration of dissolved oxygen in bottom water is saturated.

At the monitoring station (see Fig. 2.1.20) concentration of total nitrogen varies between 16–24 µmol/l with no consistent trends through the water column and year (2009-2010). Total phosphorus varies between 0.5 and 1 µmol/l with the lowest values during summer. Spring bloom occurs in March to early April with peak chlorophyll a concentrations reaching 6-8 µg/l, but on a yearly basis chlorophyll a is low at 1.5 µg/l. Cyano-bacteria blooms that common in the central Baltic Sea rarely affects the Kriegers Flak.

Seabed flora and fauna

Benthic vegetation is rare on Kriegers Flak due to depth and the associated low light intensity and, lack of hard substrate (e.g. boulders) for macroalgae. Single fonts of *Saccharina latissima* have been observed.

The benthic fauna on the shallow plain is species-poor (average 6-8 species per 0.1 m^2 sample) and characteristic for shallow, low saline areas in the western Baltic Sea (DHI 2003, DHI 2005, SoWAB 2004). Abundance (200-4000 ind. m^{-2}) and biomass (average 2-6 g ash-free DW m^{-2}) are dominated by a few species of polychaetes (*Pygospio elegans*, *Marenzelleria viridis (invasive), Hediste diversicolor*) and bivalves (*Mytilus edulis, Mya arenaria, Macoma balthica*). On the slopes species richness and abundance increases with depth averaging to 20 species per 0.1 m^2 sample at 40-42 m with dominance of polychaetes in the organic richer sediments (Zettler et al., 2003). In the Danish sector red-listed species are not present.

Fish Aquaculture

Apart from wave exposure the environmental conditions are excellent for growth-out of salmonids, especially rainbow trout and salmon due to the following environmental conditions:

- salinity is stable at 7 psu and almost equal to the osmolality of fish plasma meaning that energy expenditure to osmoregulation in fish will be low - and accordingly, that growth efficiency can be high. A low environmental salinity will also prevent infections by sea lice.
- the instantaneous dilution is high at 4000-6000 (Figure 2.1.20) implying that the well-being and growth of fish on the one hand side and the pelagic environment on the other hand will not be affected by excretes from the fish including ammonia, CO_2, medicines and release of antifouling agents such as Cu.
- on the shallow plain of Kriegers Flak more or less regular high waves and currents will erode deposits from the fish cages accumulated on the seabed as evidenced by the median grain size and low organic content under the present conditions. Therefore, permanent accumulation of organic matter in sediments below fish farm established on the shallow plains and the connected impacts on sediment chemistry and fauna will not be likely
- summer blooms of cyanobacteria occur regularly in the Baltic proper but are rare in the western Baltic Sea. The dominating species *Nodularia spumigena* produce toxin that can be lethal to zooplankton but except in laboratory lethal or sub-lethal effects on adult fish has not been described. Lethal spring blooms of *Chattonella* and *Chrysochromulina* have not been documented for the western Baltic Sea.

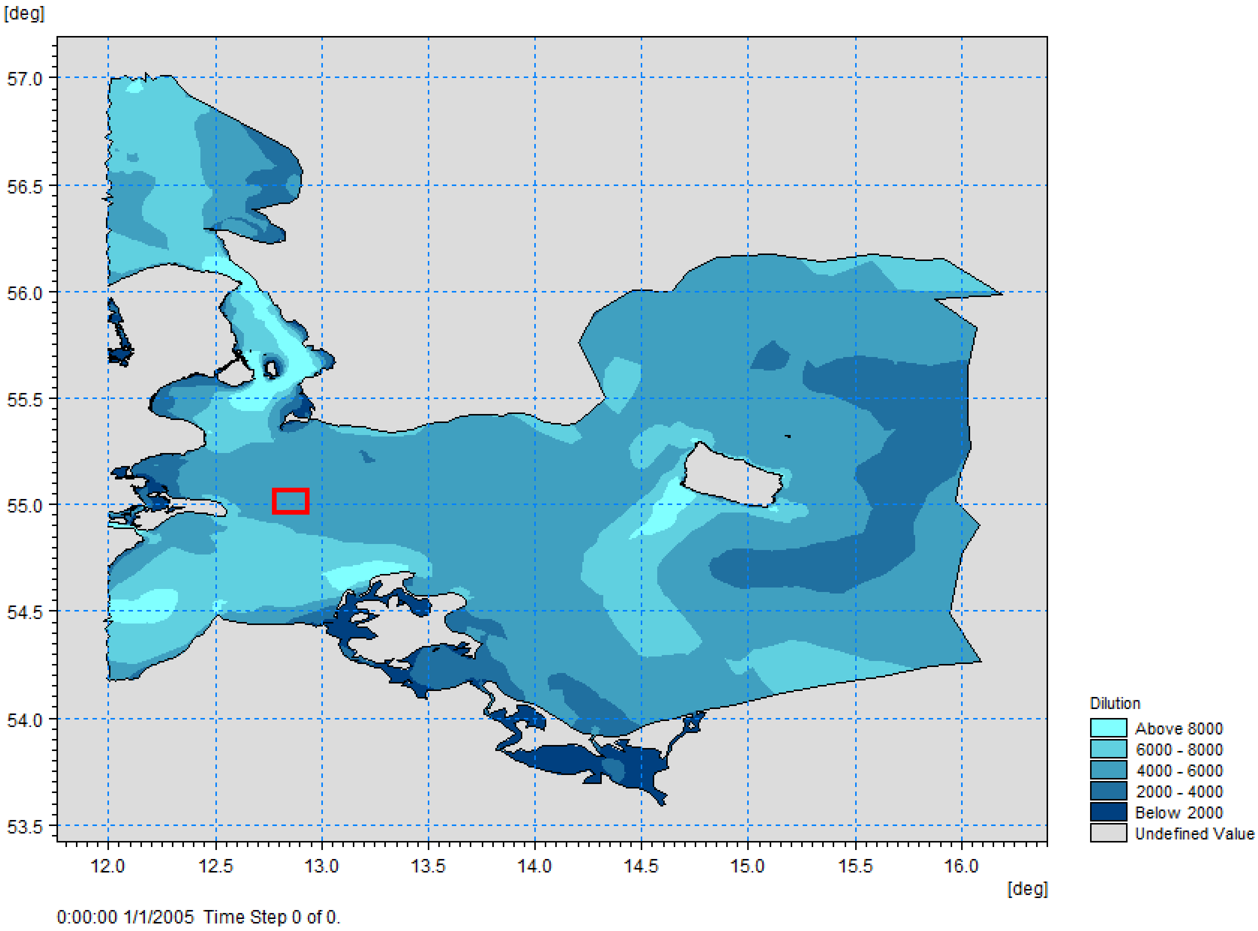

Figure 2.1.20. Dilution rate quantified using a calibrated 2-D hydrodynamic model (MIKE 21 HD). Kriegers Flak indicated by red rectangle. The model was executed for 2005 and forced by meteorology, run-off, and water level, salinity and temperature at the boundaries. For every model cell and at every stored time step (1 h) dilution rate was estimated as a near-field study by adding a tracer in fixed concentration and calculate tracer concentration 1000 m downstream of the release point (e.g. a fish farm) assuming default values of momentum dispersion coefficients. In order to take account of the underestimated currents speeds at larger depths we assumed that tracer concentration in surface waters (0-10 m) was representative of the real dilution. Yearly values of dilution were subsequently calculated for each model cell as medians.

Shellfish aquaculture

Blue mussels live widespread in the Baltic Sea at salinities above 4-5 ‰. Because growth rate, meat content and max shell length decrease with decreasing salinity, the Baltic Sea however is not considered suitable for commercial production of mussels.

Macroalgal aquaculture

With one exception commercially valuable macroalgae are uncommon in the Baltic Sea, because the low salinities prevent growth of many species. In the Baltic Sea the valuable red algae *Furcellaria lumbricalis* is generally wide-spread and often forms a belt below (6-12 m) the bladder-wrack belt where light availability is sufficient for growth red algae. Wild stocks of *F. lumbricalis* were previously exploited in Danish waters for the product "Danish agar". Today, wild stocks of this species are harvested in Estonian waters.

Recent studies have demonstrated that Baltic Sea populations of *F. lumbricalis* primarily regenerate and grow by thallus fragmentation and possibly by asexual tetraspore-to-tetraspore cycling without meiosis (Bergström et al. 2005, Kostamo 2008). Such fact opens for an "easy" culturing of a valuable red algae, that for most other species involve laborious work going through separate reproductive cycle carried out ashore in greenhouses prior to introducing algae at the growth site.

Under optimal conditions *F. lumbricalis* can attain growth rate up to 1% d^{-1}, which is markedly lower than other cultivated seaweed species, but the fact that *F. lumbricalis* grow equally well attached to hard substrates or lose-drifting above the seabed (Martin et al. 2006) probably allows to apply a cost-effective growth system. The proposed system is novel for *F. lumbricalis* using long-lines with attached "mussel-socks" of an appropriate mesh size filled with fragmented thalli of *F. lumbricalis* prior to deployment. The growth system should be submerged (e.g. below 5 m) to avoid overgrowth with annual green and brown algae. The mesh-size of socks should be scaled to the size of thalli fragments minimizing loss but allow distal growth ends easily to penetrate through meshes. Pilot growth experiments have confirmed that fragments of *F. lumbricalis* can growth unattached in mesh-bags (Kotta et al. 2008). Besides providing a sink (trap) for excreted ammonia from cultured fish the macroalgal culture system could provide some protection of cages against wave load by dissipation some of the wave energy.

2.1.6 **Social perception and constraints**[1]

Goals to participate

Goals to participate in a multi-use platform range from people, planet, and profit motivations that are described below.

People

The new forms of cooperation between the involved stakeholders that will happen in the development of a multi-use platform are an important goal for the participants. Developing a MUP can create social acceptance but also opposition for developing more intensive economic activities

[1] The information is collected on the basis of a round table discussion and interviews, both performed by Stichting DLO (Marian Stuiver). Participants were selected on the basis of involvement in the case study area of Kriegers Flak. Different categories of stakeholders can be discerned. First there are the potential entrepreneurs to participate in the development of a multi-use platform: DONG Energy, MUSH Aquaculture. Second there are governmental bodies like Fishery inspection and the Shipping Authority that have a voice in the spatial planning procedures. Third there are the Non-Governmental Organisations like the Green Centre that represent societal values. Finally parties from Universities are interviewed that have a stake in the Research and Development of the multi-use platforms.

The respondents represented:

1. DTU Kopenhagen: Scientific Institution
2. Green Center, Environmental Organisation
3. Soefartsstyrelsen: Shipping Authority
4. Fiskerikontrol øst: Fishery Inspection
5. DONG Energy: Energy Company
6. DHI: Scientific Institution
7. Mush: Fish farm Company

at sea and therefore all relevant parties should have a say in the process. One of the goals of developing a MUP is therefore to involve society in the development of economic solutions that make benefits for society. The concept of a MUP is still very unclear for society and it is very important that communication and promotion of the concept to the people are taken care of.

Planet

Participants from nature organisations and R&D centres want to increase a better combination of production and nature values and decrease the negative impacts on the ecosystem. They want to develop a MUP to understand what ecological gains can be pursued and they want to experiment and research how ecological impacts can be low, or whether there can be ecological gains achieved. The energy business and fish farm find environmental and ecological issues of big importance, as they acknowledge that they need a licence to produce from society.

Profit

For energy companies, first priority is to optimize the energy production. Aquaculture production in the same geographical area must not have negative influence upon that. If this can be achieved, energy companies are open to cooperate with other kind of off-shore activities for the sake of profit maximisation. The fish farm sees this combination as viable for continuation of the firm in the long term. Both their challenge is to combine the production of fish and energy in such a way that costs are reduced more effectively. One example is not to lose energy, but use the energy for the production of fish in confined cages. Hydrogen can be used for energy storage and possible a by-product is oxygen that can be used for the production of fish. Other ways to reduce costs is to use the same ships for transport and maintenance. Fish farms have a big vessel for feed and these can possibly be used by the energy businesses as well. Another option is to build a platform for use where both crewmembers can work and the feeding of the fish can be done.

Obstacles for participation

There are different categories of obstacles perceived by the participants that are very dependent on their perceived role in the process of developing a MUP.

Overcome distrust between stakeholders that need to be involved.

Participation should take place with all countries involved as well as the stakeholders that want to develop activities. It is very important that trust between the stakeholders is taken care of. Competing claims between the stakeholders in terms of economy and ecology need to be tackled in a mutual process and should result in new guidelines for the exploitation of the sea.

Unclear procedures for planning

Participants feel the urgent need that clear procedures for stakeholder involvement should be developed among the countries involved. At the moment Germany has a Marine Spatial Plan for the area, but the three countries together are involved in a combined Marine Spatial Plan. Developing a cross-boundary plan that includes the zoning of Kriegers Flak for different purposes is a necessary step. The aim is that there should be an equal division of nature conservation as well as economic activities and present shipping and transport lines should be taken into consideration as well.

Short of long term permits

It is an obstacle for the fish farm companies how to get the right permits for the economic exploitation of the sea. For instance, coastal authorities need to be involved more intensively in the process as they are responsible for giving permissions to constructions at sea. Their job will change when MUPs are developed. They have to develop new guidelines for the administration of the sea territory within their authorities.

Ecological constraints

Part of the sea bed area will be taken up by the foundations of the wind turbines and part of the sea will be destined for the fish cages. This will have an effect on the habitats in their living environment. But the foundation and scour protection of wind turbines have proved to become an artificial reef in which algae and invertebrates appear to do well. The foundations are quickly colonized and create entire communities of marine life[2]. So there are also possibilities for improving sea life and ecological conditions that need to be explored

Conditions for the design

Different conditions for the design are mentioned by the stakeholders that involve a range of technical, ecological and socio-economic conditions for design.

Technical

There are also different logistic constraints perceived by the participants on maintenance and monitoring, anchoring and transport. When a wind farm and fish farm are combined, more ships will enter the area, which means more traffic and higher risks of accidents for the people and technology involved. However, the entire wind farm will be designated as a cable protection zone, meaning that anchoring, trawling etc. will not be allowed.

There is a practical problem when you are combining wind turbines and fish farms at sea. It is the potential risk of internal damages, for example if the anchors of the fish farm are drifting into the cables of power supply, or if the fish cages are damaged by the wind turbine construction. In order to reduce the risks, the MUP should be clearly marked out and will be armed with technical monitoring equipment. Also a risk assessment is needed. Possibly two shipping routes that pass Kriegers Flak need to be changed, for instance the Ferry to Travemunde. Second, when fish cages are located between the wind turbines this means that transportation is more restricted. Good guidelines and rules need to be endorsed to ensure safety of the people, the vessels, the cages and wind turbines involved.

Ecological

There should be no impact on the environment and the ecological conditions of the seawater and seabed. One condition involves the preservation of the artificial reefs that are located under the surface. Potential scour protection around foundations may act as artificial reefs. Disturbance of these habitats can be avoided when the fish farms are placed far away from the artificial reefs themselves. In the positioning of the fish cages, one should take this into consideration.

Socio-economic

A MUP will affect the landscape to a greater or lesser extent. In the view of the participants there should not be any effect on views from shore. However some of the wind turbine towers at Kriegers flak would be below the horizon, since the wind turbines are located around 30 km off shore. Depending on the weather conditions, the farm will seldom be clearly visible from the coast.

[2] www.vattenfall.se/kriegersflak

Perceptions of the public and the image of wind turbines and fish farms are variable. Fish farms and aquaculture at sea are less accepted by the audience then wind farms. However, public images can change. There is a debate that argues that aquaculture is not polluting and produces healthy food in an environmentally very efficient and correct way.

Focus or open design

Participants differ in whether they will participate depending on the range of economic options. Some express to start with combining wind energy and fish farms and build from there. However, it might be more practical and economically efficient to divide the area in the sea and separate some of the physical installations, for example the cages and wind turbines, and then combine others, such as feeding stations and the maintenance ships. It does not necessarily have to be one big platform.

Others suggest to leave options open and make the design in such a way that also for instance tourism and energy storage is possible. Others warn that there should not be overriding conflicts between the economic activities and that the sky is not the limit. In the future there could be totally new designs needed that have spatial effects.

2.2 Active morphology site, North Sea and Wadden Sea

2.2.1 Short site description

The most important MERMAID benchmark for the North Sea site is an area with typical active morphology and environmental characteristics (Fig. 2.2.1).

The Dutch MERMAID partners have unanimously decided that the interesting test study area lies above the Waddenzee Islands in the North of the Netherlands. In this area the Dutch authorities (Rijkswaterstaat) awarded 3 permits for larger offshore wind farms, the so-called Gemini project. These 3 projects are named Buitengaats (300MW), Clearcamp (275 MW) and ZeeEnergie (300MW) and fully acquired by Typhoon Offshore in July 2011 (http://www.typhoonoffshore.eu/projects/gemini/).Two projects, Buitengaats and ZeeEnergie ,were granted a subsidy (SDE, Dutch Government) in May 2010 and are currently in the process of being brought to financial close (spring 2013). The third project, Clearcamp is still without subsidy and may serve as a future test field for new offshore wind technologies. This means that for the Gemini site already ongoing impact studies are conducted regarding safety and stability of monopile constructions (a.o. Deltares) as well as for the environmental impact (a.o. IMARES).

WTG:	Siemens
Power:	600 MW
Depth:	30-40 M
Distance from the coast:	85 km
Swept area:	2 x 34 km2
Hub height:	88,5 M (from sea level)
Rotor diameter:	130 M
Annual production:	2.6 TWh per year
Powering:	> 785.000 households
Operational since:	Construction starting 2013
CO2-emissions avoidance:	1,250,000 Tons

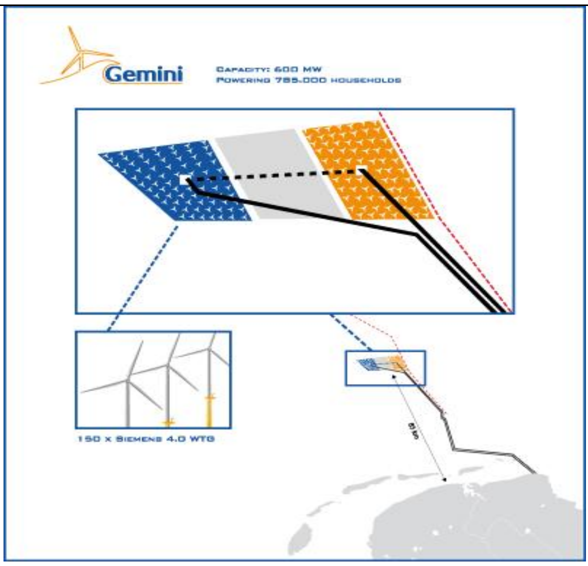

Figure 2.2.1 - Gemini project data: Netherlands, Wadden Sea Islands

The exact location of the North Sea site is well-known and more details can be found on the website: www.4coffshore.com/wind farms/gemini-netherlands. The granted Gemini wind farm concession and permit are only for single use activities. The MUP possibilities are just conceptually based and fully under discussion.

2.2.2 Current policy, management and planning strategies

It is argued that there are opportunities for growth in aquaculture in the European Union EU, to play an important role in the supply of aquatic seafood for human consumption. In 2009 the EU published a communication to give new input for the sustainable development of European Aquaculture (SEC 453/454). The three main objectives where to increase competition, securing its sustainability improving governance and ensuring a business-friendly environment in all governance levels (local, national and EU).

In the Netherlands sustainable development and realization of policy for aquaculture is stimulated through the aquaculture innovation platform. Policies for aquaculture can be divided into coastal and offshore aquaculture. In the Dutch EEZ, wind energy farms will be placed in offshore areas where, in the current situation, no aquaculture activities take place. The Dutch aquaculture sector is dominated by shellfish cultivation in the coastal areas. In this context the Wadden Sea, Oosterschelde, Westerschelde and the Voordelta are considered the most important areas.

In the next paragraph we will describe the possibilities of aquaculture activities in offshore wind energy parks looking at the current policy.

Offshore Aquaculture (Agreement between Countries and Country Specific Agreement)

In 2011 Rijkswaterstaat stated that smart uses of space could be a solution to the shortage of space on the North Sea (Verhaeghe et al, 2011). Aquaculture inside off- shore wind energy parks was mentioned as a possible smart use of space, providing opportunities for clever entrepreneurship. However, in the Integral Management plan for the North Sea (Integraal Beheerplan Noordzee, 2006) there is no space allocated to offshore aquaculture for the Dutch part of the North Sea. This means that aquaculture activities in wind energy parks needs to be applied for through permits. In addition to these permits there is an integral balancing framework aiming to help managers in coordinating permit restricted activities with efficient use of space and nature protection values).

This framework exist of five tests: 1. Defining spatial claim, 2. Precaution, 3. Usefulness en need, 4. Location choice and spatial use and 5. Reducing the effect and compensation. For new activities this means that they have to reduce or prevent negative effects on the environment, which is tested using precautionary test. They have to address why it is important that this activity takes place in the North Sea using a social cost-benefit analyses. The space needed for the activity must be carefully chosen and sufficiently used and when the activity compromises important natural values these need to be compensated in another area.

In case of offshore wind energy parks there is a safety zone of 500 meter around static objects such as turbines(IBN) all countries can designate such a safety zone (cf. UNCLOS).This means no shipping activities can take place within 500 meter of the turbine. However exceptions on this rule could be made through permit application (IBN).

The Integral Management plan for the North Sea states that it is unlikely that fish cultivation on open sea is to happen. Open systems are economically attractive but environmentally unfavorable against closed systems. Furthermore, scientist question whether the environment in the Dutch parts of the North Sea allows for fish aquaculture (Reijs et al, 2008). Mari culture on open sea is more positively advocated when floating mussel docks become successful (IBN).

France and Belgium have a similar attitude towards aquaculture activities in wind energy parks as the Netherlands. They have designated a 500 meter safety zone round the turbines and do not allow shipping inside the area. Denmark and England have another attitude towards activities inside wind energy parks. Denmark and the United Kingdom expect fishery and shipping activities to continue as before and when fishery activities are disrupted because of the turbines, claims can be expected. In Denmark the right to fish is recorded in the constitution and the United Kingdom only applies a safety zone with maintenance and building activities (ILVO).

Specific Legislation and Policies Wind energy

In the "Roadmap for moving to a competitive low-carbon economy in 2050" (COM(2011) 112 final) the European Commission set an ambitious long-term target; the reduction of greenhouse gas emissions in 2050 by 80-95% compared to 1990. The roadmap, part of the "Europe 2020 flagship initiative for a resource-efficient Europe" states that in 2020, EU member states should have reduced greenhouse gas emissions by 20%, by increasing the share of renewables in the EU's energy mix by 20% and improving energy efficiency by 20%.

These EU wide ambitions underlie Dutch energy policy. To understand the essence of Dutch energy policy, is important to identify the three "perspectives" on energy policy as formulated in the "Energierapport 2011". First, and building upon the EU targets, there is the ambition to move towards a cleaner energy supply. Second is the perspective that identifies the energy sector as an important economic sector to be stimulated. Third, there is concern about the reliability of energy supply. The identification of these three perspectives signify a changing focus in energy policies where sustainability now goes hand in hand with economic performance. Consequently, five priorities for Dutch energy policy are identified:

1. A modern industrial policy is required to improve the performance, and international position, of the Dutch energy sector.
2. The supply of renewable energy needs to be enlarged. This is a long and short-term objective. In the long run, emphasis is on improving the competitiveness of renewables. In the short run, focus lies on improving the impact of the existing subsidy program SDE+ and on mandatory use of biofuels in power generation.
3. All energy-options need to be kept open towards 2050. This means the Dutch policy does not include any technology (for example nuclear, CCS). All are deemed necessary to achieve the long-term objectives.
4. Green deals are formulated in which government and society (profit and non-profit) make arrangements to invest innovation that contributes to the achievement of policy objectives.
5. Investments in a well-functioning European energy market are required, This requires mutual adjustment between countries, investment in transport capacity and reservation of sufficient space for energy production.

These are the general priorities of Dutch energy policy. When it comes to policies and legislation for offshore and coastal wind, the following aspects require attention;

- Specific policy objectives in place to enable offshore and coastal wind;
- Existing subsidy programs to support wind energy;
- Spatial policies that regulate wind energy;

- Requires permits to develop wind energy projects;
- Innovation agenda for future development of wind generation.

Policy objectives for offshore wind

In current Dutch energy policy, a clear policy for offshore wind energy is lacking. This is caused by a reorientation in energy policy on the one hand, moving away from offshore wind energy and the development marine spatial plans on the other, moving towards offshore wind.

In earlier energy policy, offshore wind energy was identified as an important sector, required to achieve formulated objectives. These objectives were laid down in for example the 2007 “Werkprogramma Schoon en Zuinig” in which a growth of offshore wind energy capacity of ca. 500 MW/year was foreseen. At that time, reservation of sufficient space in marine spatial planning was considered the main bottleneck for development of offshore wind energy. In following marine spatial plans, these problems were addressed (see below).

In 2008, the Dutch government formulated the objective to reach 6000 MW production capacity for offshore wind energy. In 2010, the Minister appointed the Taskforce Windenergie op Zee with the objective to identify bottlenecks for achieving the 6000 MW target. The Taskforce identified a number of bottlenecks, including for example problems in supply – and investment chains and lacking capacity at the government to deal with the topic (Taskforce Wind op Zee, 2010) Until 2010, offshore wind energy was subsidized under the SDE program (Stimulering Duurzame Energie). The Taskforce plead for optimalisation of the SDE program – from an offshore wind perspective. However, as illustrated in the next paragraph, the new 2012 SDE+ program excluded offshore wind energy.

An important issue concerning the production and transport of renewable energy is the integration of new production capacity in national grid. It is the responsibility of national grid owner Tennet to avoid congestion and secure safe transport and supply. Under EU legislation (2009/28/EC), Member States are required to give renewable energy priority on the national grid. This requirement was implemented through an adjustment of the Dutch Electricity Law but pending a discussion on the allocation of the cost of congestion management, the Law is not yet approved. A different discussion issue on grid integration concern the costs for connection of offshore wind energy parks to the national grid. Under current Dutch law, these costs are to be made by the project developer.

Subsidies to stimulate renewable energy

The two existing offshore wind energy parks in the Netherlands are financed through the MEP-program (Milieukwaliteit Elektriciteitsproductie) which has come to an end. In May 2010, two other developments received subsidy under the 2009 SDE-program; Buitengaats C.V. en ZeeEnergie C.V. Both are located in the area of study, above Schiermonnikoog and together allow for the realization of 600 MW of offshore wind energy production. Both are now owned by Typhoon Offshore . In November 2011, the remainder of the budget was allocated to Dutch energy company Eneco for the (to be realized) Q10 offshore wind energy park.
The main current subsidy program that targets the production of renewable energy is the SDE+ program (Stimulering Duurzame Energie). The rationale behind SDE+ is that renewable energy is more costly to produce but need stimulation to development markets and more efficient technologies. Hence the government subsidizes part of the production costs of renewable energy.
In 2012, the following production methods are eligible for subsidy;

- Waste incineration;
- Biomass (Digestion, direct burning or fermentation);
- Direct burning of biomass;
- Solar energy;
- Biogas from wastewater treatment plants;
- Wind energy;
- Hydropower;
- Geothermal energy.

There are a number of limitations to the subsidy program. First of all, there is a budget cap. Every year, the Minister decides what is available for the program. In 2012, € 1,7 billion is available. Secondly, the program prioritizes cheap renewables over more expensive production methods. The available budget is allocated to different production methods based on the subsidy required per unit of energy production (€/kWh). The cheaper renewable energy production, the more budget is available.

From 2012 onwards, offshore wind energy is no longer eligible for subsidy under the SDE+ program. It is argued that it is to expensive – compared to other production methods – and focus should first be on innovation, reducing cost price. For clarification, existing offshore wind parks in the Netherlands are subsidized under different programs that are longer open for new applications (MEP, SDE Tender Wind op Zee, 2009).

Offshore wind energy in Dutch marine spatial planning

The first two offshore wind energy parks in the Dutch territory of the North Sea were realized in a period of time in which there was no specific marine spatial planning strategy for offshore wind energy parks. Applicants had to use Environmental Impact Assessment to assess the impact of construction and operation on the environment. Although a large number of permits were requested, only two parks were permitted. Up to this day, these so-called Round 1 parks are the only two realized Dutch offshore wind energy parks.

Permits for the so-called Round 2 parks were also asked prior to the development of a marine spatial plan for offshore wind parks. In Round 2, 12 permits were issued for offshore wind energy parks. Final permission was given in between 2009 and 2010. Out of these 12, only 3 parks received SDE subsidy; the Q10 park and two parks North of Schiermonnikoog. On April 1, 2008 a moratorium on new permits for offshore wind energy parks was announced. Until further notice, request for new permits will not be taken into account. A summary of Round 1 to Round 3 is provided in the table 2.2.1 below.

In 2007, the Dutch government presented their vision on how the Netherlands should deal with water issues. Sustainable, climate-proof, and strengthening the economy were key words. The vision was important because it provided input and direction to the first Dutch National Waterplan (Nationaal Waterplan 2009-2015). Is For the North Sea area, the objective is to “make the North Sea more sustainable”, whilst keeping in mind the first priority: safety and protection from floods.
Accepted on December 22, 2009, The National Waterplan integrated all areas water, from offshore and coastal to rivers and inland water. Based on the Waterwet and the law on spatial planning (Wet ruimtelijke ordening/Wro), the National Waterplan was also the Structure Plan (Structuurvisie),

describing the rough outline of spatial planning of future water-related developments. The National Waterplan follows an area-oriented approach, for each water basin, specific objectives are formulated and a spatial plan is made to accommodate developments.

One of the ways to make the North Sea more sustainable is to reserve sufficient space for offshore wind energy parks. Informed by the 6000 MW ambition, it was envisioned that at least 1000 km2 needed to be reserved for wind park development. Future developments (after 2020) might require more space. Other developments, such as Carbon Capture and Storage (CCS) are also envisioned and the need for mutual adjustment between functions is emphasized. In the National Waterplan, the options for multiple uses of space are explicitly mentioned.

In the Policy Note North Sea 2009-2015 (Beleidsnota Noordzee 2009-2015), North Sea policies are further elaborated. After a first identification of areas where offshore wind energy could be developed, a second step was to balance the interests of the various users of the North Sea. This exercise resulted in the identification of two areas for offshore wind development and two so-called “zoekgebieden” (search areas) for future developments. In this policy document, it is explicitly mentioned that co-use offshore wind energy parks, for example for recreation, fisheries and aquaculture, should be allowed as much as possible and needs to be discussed with the involved parties as the policy is implemented.

In 2012, the Minister decided that the permits for the 9 remaining park are valid until 2020, to give more time for realization. At the moment of writing this report, summer 2013, the Minister decided to examine the possibities to enhance offshore wind developments in the nearshore zone, i.e. within the 12 nautical miles from shore.

Table 2.2.1 - Current situation for offshore wind energy in the Netherlands.

Dutch offshore wind: Three “Rounds”
Round 1:Two offshore wind energy parks realised: the (1) “Prinses Amaliawindpark” off coast of de kust van IJmuiden and (2) the Offshore Windpark Egmond aan Zee (OWEZ) off coast of Egmond aan Zee. Together they have a capacity of 228 MW. Both are realised drawing upon MEP-subsidy.
Round 2: Twelve permits are granted to develop new offshore wind parks. Three parks are eligible for subsidy under the SDE program: two parks North of Schiermonnikoog (600MW) and the Q10 park (150MW). The remaining permits are valid until 2020.
Round 3: A new system for granting concessions is developed and expected to be in place ultimo 2015.

From designated area to project development: regulations and permits

An offshore wind energy park requires a permit, based on the “Wet beheer rijkswaterstaatwerken” (Wbr). Before such a permit can be granted, project developers have to go through the environmental impacts assessment procedure. When applying for a permit, they are obliged to deliver a “SIA” (strategic impact assessment) which assesses the environmental impact of their

envisioned project. Before realization of the project, a “MER” is required to assess the environmental impact of the definitive project.
Dutch legislation differentiates between two EIA procedures, the ‘full’ and ‘simplified’ procedure. Applications for offshore wind energy follow the normal procedure. The following table 2.2.2. describes the procedure for EIA in the Netherlands.

Table 2.2.2 - EIA procedure (www.ncea.nl)

procedure step-by-step
- proponent notifies competent authorities (EIA)
- public announcement, start of procedure
- consultation designated authorities - public consultation
- *optional: scoping advice NCEA (Netherlands Commission for Environmental Assessment)*
- write and publish SEA/EIA report, including description of alternatives
- competent authority publishes SEA/ EIA report and concept decision
- public consultation SEA/EIA report - consultation EIA report designated authorities
- review advice NCEA mandatory
- competent authority publishes decision and justification
- evaluation

In this procedure, the project developer can receive feedback from the NCEA, stating which subject is to be addressed in the assessment. In 2007 the NCEA required the project developers to fulfill the following criteria for impact assessment of offshore wind energy parks:

- To check how the proposed project fits into spatial policies in place;
- To make an “appropriate assessment” conform Article 6, paragraph 3 from the Habitat Directive;
- To describe if further analysis of the balance between nature’s interest and society’s interest is necessary;
- To describe various alternative to the project plan;
- To describe possible mitigating measures;
- To quantify the effects where possible;
- To use the most up-to-date information available.

The procedure of environmental impact assessment also includes public consultation in which the results are made publicly available and the public has the opportunity to react. In total, the procedure can take more than a year. If a project developer has gone through the procedures for EIA and permitting successfully, a 20 year concession is granted to build a wind energy park. The system of concessions stems from the Mining Act and grants the developer the possibility to build permanent structures and extract resource. In the concession, additional requirements can be included. For Dutch wind energy parks, restrictions for co-use stem from the concession in which the competent authorities have included “restricted” areas surrounding the wind energy constructions where no ships are allowed.

Top-sector Energy and the Innovation Contract “Wind op Zee”

In 2011, the Dutch government changed the funding structure for applied research. It now focused on 9 so-called “Topsectors” which are considered of crucial importance for the Dutch economy. In these sectors, the Netherlands has a strong international position, to which further applied research is to contribute. Energy is one of these sectors. Effectively, this means that budget is made available for applied research. This budget is allocated in cooperation with the companies who also have to match by contributing financially.

Offshore wind energy is seen as one of the promising future technologies, to benefit the Dutch economy. It is argued that under current conditions, cost prices are too high and for that reason emphasis is put on cost price reduction. Research institutes, companies and government together discuss the allocation of money to the different research project in so called innovation contracts. The innovation contract for offshore wind energy is currently elaborated. At information day in June 2012, the outlines of the contract where presented and companies and research institutes were asked to submit research proposals aimed to cost price reduction. Multi-use platforms were discussed by various participants and it is expected that proposal are submitted.

Timeline

The following table 2.2.3 illustrates the development offshore wind energy in the Dutch North Sea.

Table 2.2.3 - A timeline of the development of offshore wind energy in the Netherlands

Year	Policy and legislation for offshore wind	Project development
1998		First initiative to develop offshore wind parks
2002	Permits for first offshore wind energy parks granted.	
2006		Start of construction first offshore wind energy park "Prinses Amalia"
2007	Policy objective formulated to realize 6000 MW offshore wind energy by 2020	
2008		Realization of the first two offshore wind parks
2008	Moratorium; request for new permits are not accepted until further notice	
2009	National Waterplan formalized in which space for offshore wind energy is reserved	Permits provided to 12 to be developed offshore wind parks
	National Waterplan: options for combinations of functions need to be kept open	
2010	SDE subidy granted to two offshore wind parks (North of Schiermonnikoog)	
2011	SDE subsidy granted to Q10 offshore wind park	
2012	Validity of permits extended	Procedure for realization of Q10 wind park started
2012	Offshore wind no longer eligible for subsidy under SDE+ program	Gemini parks await further action from project developer
2012	Formalization of Green Deal offshore wind and subsequent innovation agenda	

2.2.3 **Metocean conditions and renewable energy potential**

Wind conditions

The mean wind speed is presented in Fig. 2.2.2 .Wind statistics as a wind rose and Weibull distribution is shown in Fig. 2.2.3 based on Envisat ASAR.

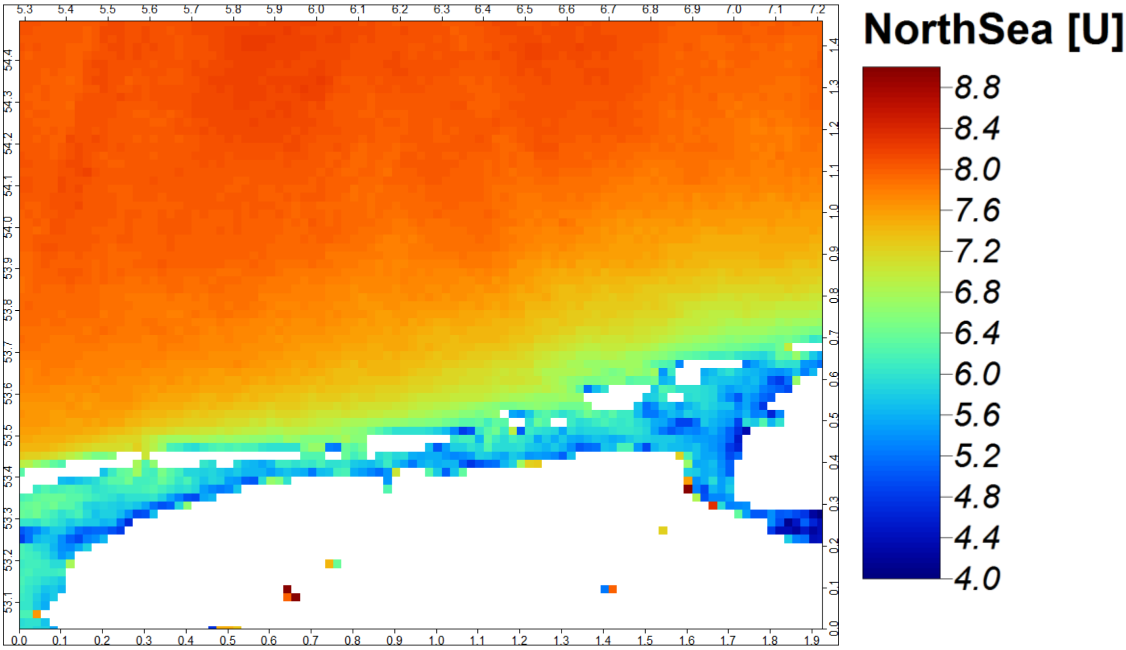

Fig 2.2.2. Map of mean wind speed from Gemini based on Envisat ASAR wind fields

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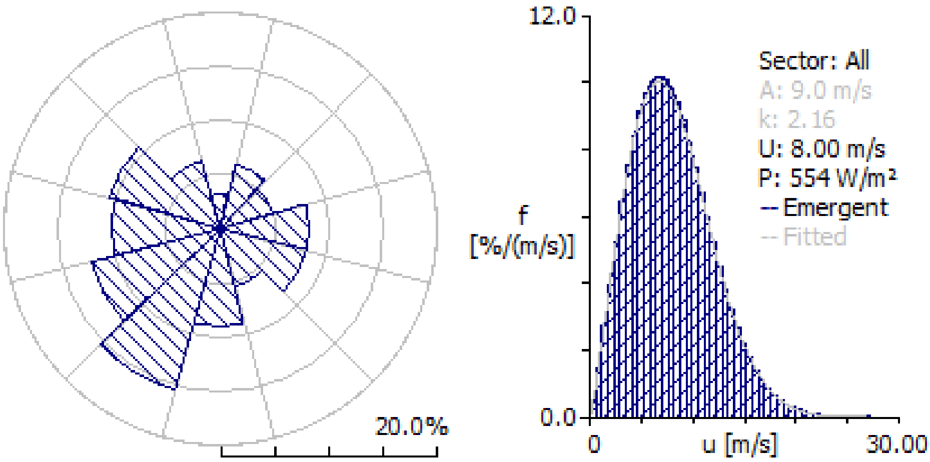


Fig. 2.2.3 Wind rose and Weibull distribution at 10 m at 54.04°N 5.96°E in the Southern North Sea observed from Envisat ASAR.

Normal wave conditions

Figure 2.2.4 shows the rose of the significant wave height H_s, and mean wave direction, MWD, for the entire dataset. The figure shows that the wave climate is characterized by waves predominantly from Northwest, which is also the sector from which the higher and longer waves come. Waves from the Dutch, German and Danish coasts (from south, southeast, east and northeast) are generally less frequent, which can be explained by the shorter fetches for those directions. The significant wave height is generally lower than 2.1 m. The peak period varies generally between 2 s and 10 s. The highest significant wave height in the entire dataset is 10.99 m (February 17, 1962).

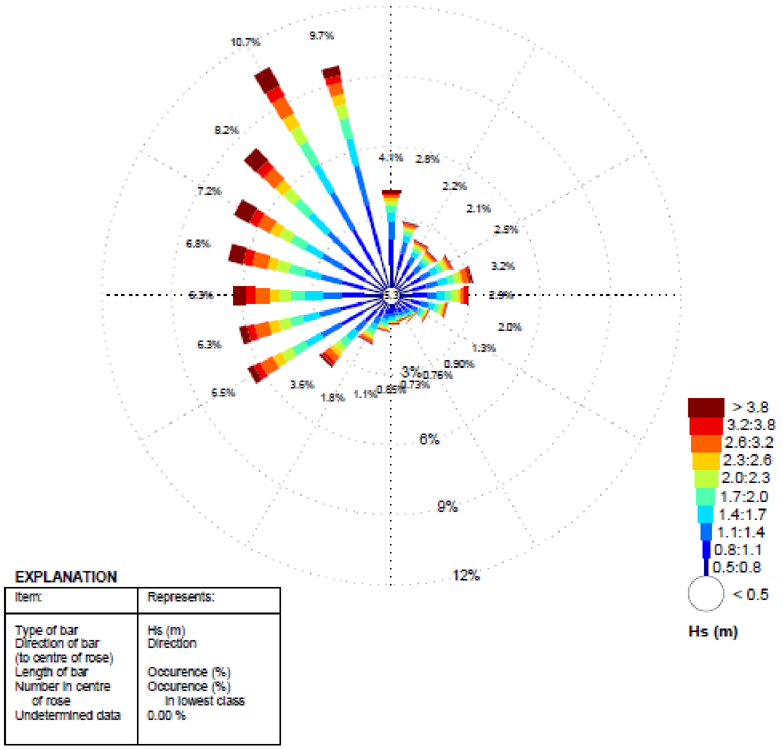


Figure 2.2.4 – Wave rose at Gemini

Extreme wave conditions

Table shows estimates of significant wave height (H_s). This table also shows the maximal wave height, H_{max}, which is defined as $H_{0.1\%}$ (largest wave height in 1000 waves during a certain sea state). They were determined using the Composite Weibull distribution developed by Battjes and Groenendijk (2000). This distribution is preferred to the Rayleigh distribution in regions where the highest waves in the sea state are depth-limited. A depth of 30 m MSL was assumed in the computations. The slope used (1:250) is steeper than the characteristic slope in the Gemini region, but it was chosen because it is the mildest slope considered by Battjes and Groenendijk (2000). Also, these authors focused mainly on sea states with a higher rate of depth limited wave heights than what is expected in the Gemini region. These differences in conditions may lead to an overestimation of the depth induced wave breaking by the Composite Weibull distribution. For Rayleigh distributed waves the ratio between $H_{0.1\%}$ and H_s is 1.86. Therefore when the Battjes and Groenendijk estimates are lower than the Rayleigh limit, the confidence interval upper bounds given in Table always contain the Rayleigh value. The $H_{0.1\%}$ estimates obtained using the Battjes and Groenendijk model should be considered as the best estimates and it is advised that they are likewise interpreted in the design process.

The return values estimates of H_s are also associated with the parameters peak period (T_p (s)), and the wind speed at 10 m height ($Wind_{10m}$ (m/s)). These are presented in the table below. The table also includes the estimates for the extreme crest height of the maximal wave height. To determine the extreme crest height of the maximal wave height, the Rienecker-Fenton wave theory (Rienecker and Fenton, 1981) was used. This maximum crest height is determined on the basis of the total water depth, the maximum wave height (*Hmax*) and the corresponding wave period. The maximum crest height is presented in the table below for the return periods of 1 and 50 years.

Please note that in the tables the point estimates are given as the value before the brackets. Besides that, the 95%-confidence intervals are provided (the values between the brackets).

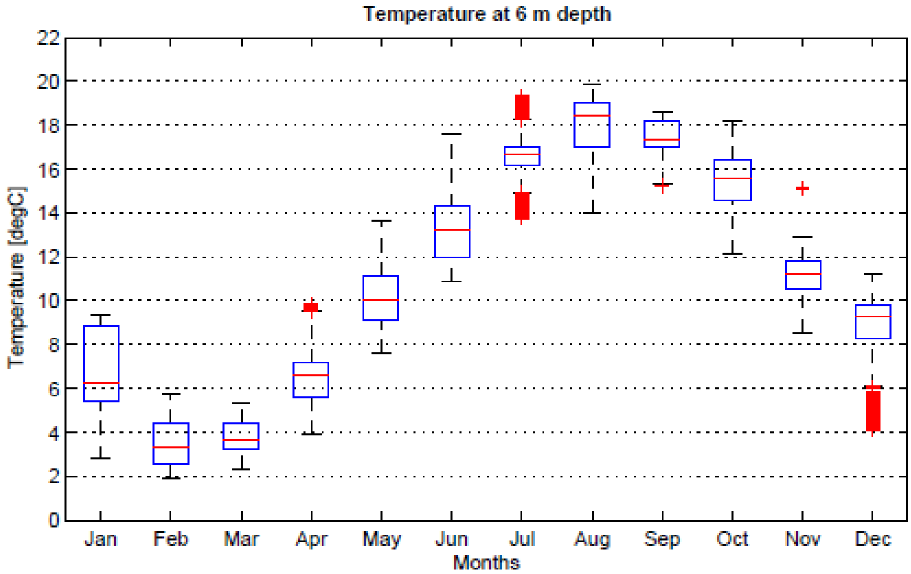
Table 2.2.4: Significant wave height return values

Return period	H_s **[m]**	T_p **[s]**	H_{max} **[m]**	**Extreme crest height [m]**	$Wind_{10m}$ **[m/s]**
1/1 yr	7.86 (7.61, 8.09)	12.99 (12.74 15.12)	13.21 (12.94 15.05)	8.73	21.90 (21.57 24.63)
1/50 yr	11.15 (10.15 12.51)	16.00 (13.21 17.15)	16.78 (15.65 23.27)	12.42	25.73 (22.18 27.13)

Sea water temperature

The Fino1 database contains seawater temperature data for the period 2004 to 2013 (with some gaps in between) at different depth levels. Analyses have been performed for the temperature data at 6 m and 25 m below the. The monthly variation in seawater temperature is shown in the statistical box plot in Figure 2.2.5.

The sea temperature varies between 2 °C and 20 °C. The lowest sea temperature occurs in the months February and March (on average between 3 °C and 5 °C). The highest sea temperature occurs in August (on average between 17 °C and 19 °C). The statistical box plots show no substantial difference between the different vertical layers, indicating that the temperature is well mixed over the water column, as is the case for salinity.



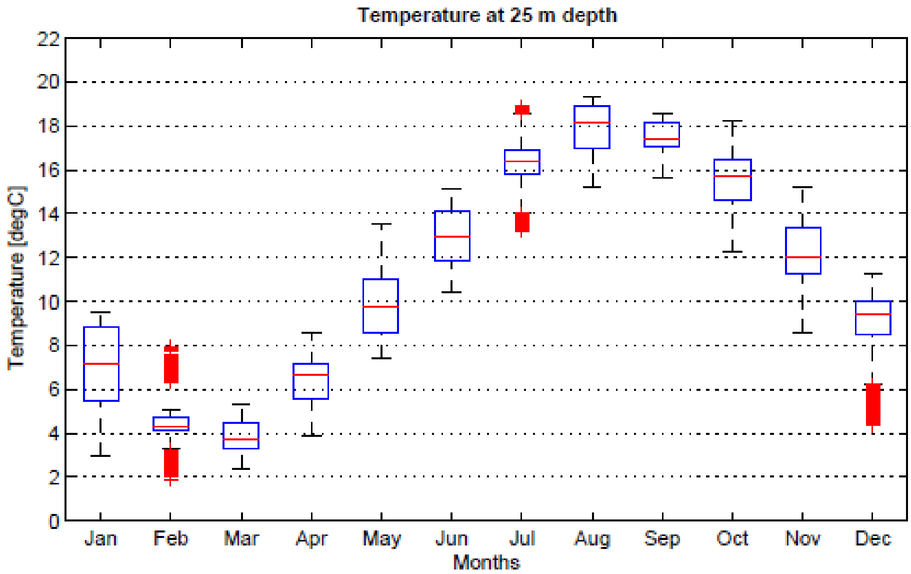
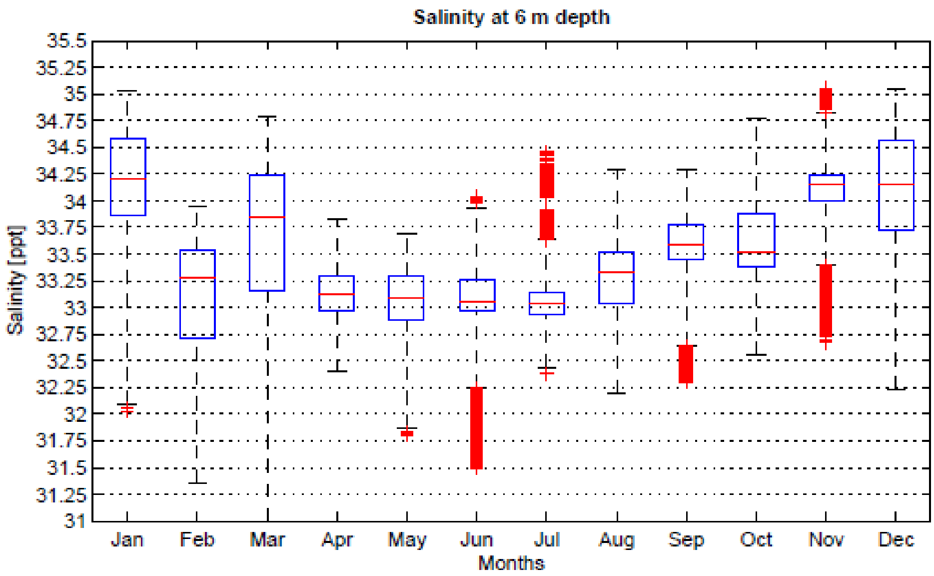


Figure 2.2.5 – Sea water temperature at Gemini

Salinity

The Fino1 database contains salinity data for the period 2004 to 2013 (with some gaps in between) at different depth levels. Analyses have been performed for the salinity data at 6 m and 25 m below the surface. The monthly variation in salinity is shown in the statistical box plot in Figure 2.2.6. The box plots show for each month the lower and upper quartiles of the data (the blue box), the median (horizontal red line within the blue box) and the extent of the data (the black whiskers). Outliers are denoted by the red markers and have been defined as measurements beyond 1.5 times the interquartile range from the box.

The salinity mainly varies between 32.5 and 35 ppt. In summer the salinity is lower than in winter (the average difference is in the order of 1 ppt). The relatively low salinity values in the month February can be explained by the fact that for some years data is missing in the month February, which introduced a biased outcome. The statistical box plots show no substantial difference between the different vertical layers, indicating that the salinity is well mixed over the water column.



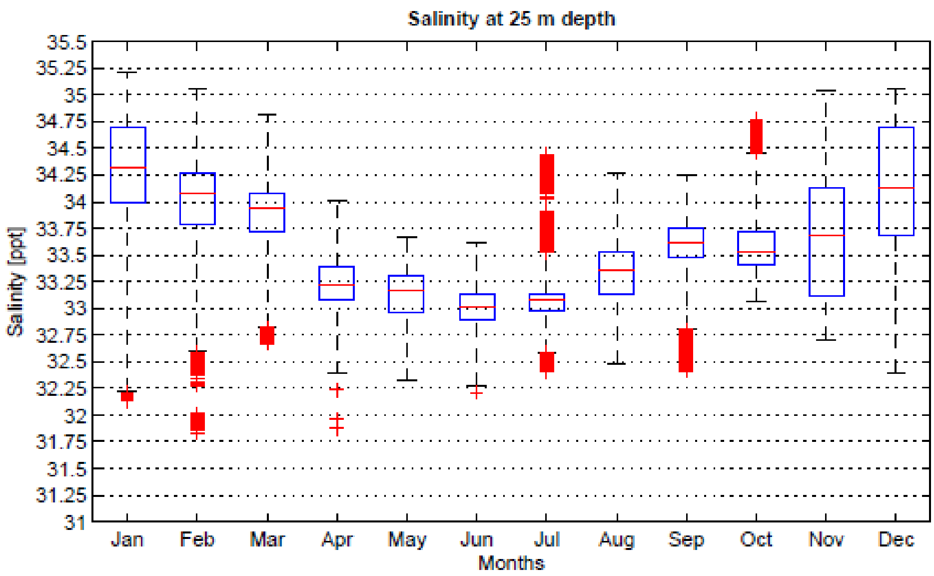


Figure 2.2.6 – Salinity at Gemini

2.2.4 **Hydromorphological analysis**

Figure 2.2.7 shows the rose of the coastDat depth-averaged current magnitude U_{mag}, and the depth-averaged current direction *DD* for the entire coastDat dataset. The figure show that the current direction is predominantly East and West, which is parallel to the Dutch and German coastline. The currents from the West (flood currents) are generally slightly stronger than the currents from the East (ebb currents). The current magnitude varies normally between 0 m/s and 0.6 m/s.

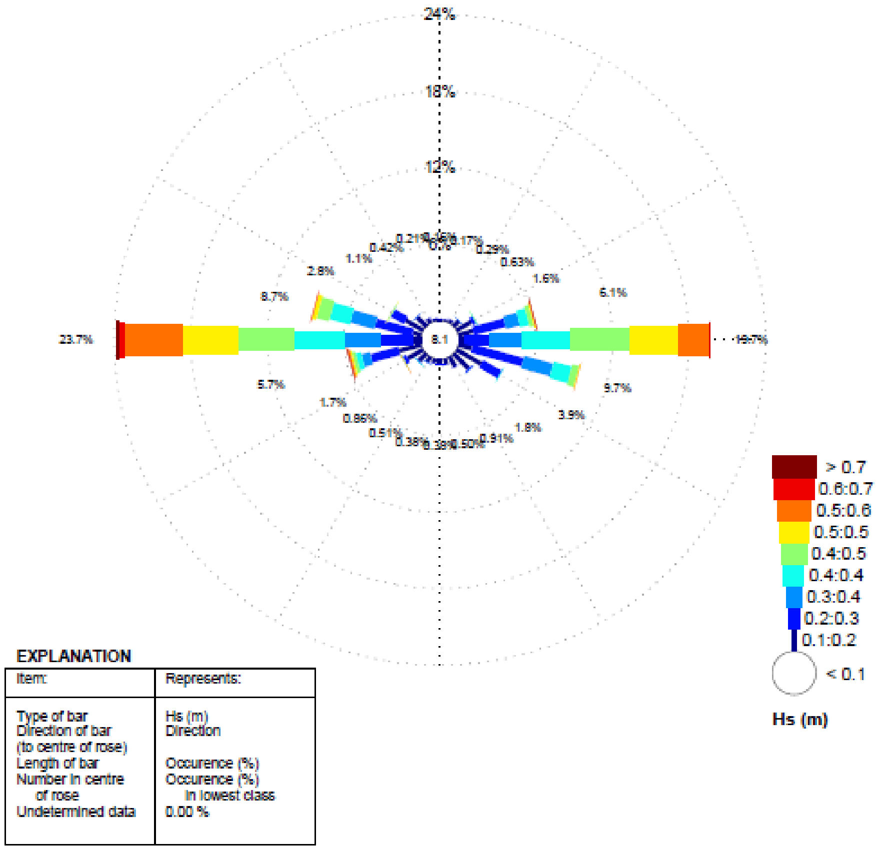


Figure 2.2.7 – Currents at Gemini

Extreme currents

Current magnitude return values were estimated using extreme value analysis. Table 2.2.6 shows the omni-directional depth-averaged current magnitude return values. The 1/1 yr current magnitude return value is 0.74 m/s. The 1/50 yr current magnitude return value is 0.93 m/s.

Table 2.2.5: Current magnitude return values

Return period	Extreme current magnitude (m/s)
1/1 yr	0.74 (0.73, 0.75)
1/50 yr	0.93 (0.87, 1.01)

2.2.5 Environmental characterisation

This subsection describes flora, fauna, habitats and species colonizing the area, protected or exotic/invasive species, water characteristic parameters useful for aqua-farming (salinity, temperature, nutrients, etc.), pollution problems, etc.

The North Sea is a biologically rich and productive region. The densely populated, highly industrialized countries bordering the North Sea conduct major fishing activities, carry out oil and gas offshore activities, extract sand and gravel, use it for dumping dredged material and for pipelines and cables. The North Sea is one of the most frequently traversed sea areas of the world and two of the world's largest ports are situated on the North Sea coast. In addition, the coastal zone is used intensively for recreation. Regular assessment and monitoring of the North Sea have been carried out for years. The Quality Status Report 2010 for the Greater North Sea (OSPAR 2010) comprises the latest comprehensive assessment.

The North Sea is made up of a mosaic of different habitats that are important for the ecological functioning of the North Sea. A general conservation strategy is to protect the quality and quantity of habitats to protect the organisms living in and contributing to the habitats, and to preserve the ecosystem structure and functioning. The North Sea is very productive, due in part to large inputs of nutrients leading to high primary production, the basis for all food chains. The intricate webbing of the food chains in the North Sea makes the ecosystem durable, yet vulnerable to major alterations such as overexploitation of single species, which can be deleterious (OSPAR 2010).

2.2.6 Social perception and constraints

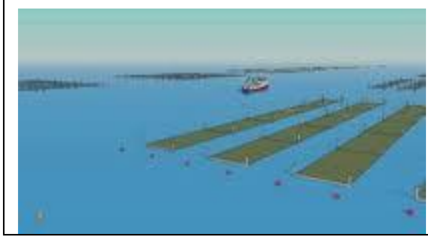
The granted wind farm concession and permits for this North Sea site are only for single use activities. The MUP possibilities are just conceptually based and fully under discussion. Since a year there are meetings with 3 Dutch focusgroups, not only for this site but also for 2 more concessions for large scale offshore wind farms, the IJmuiden site and Borsele site. During the yearly North Sea meetings researchers and stakeholders are discussing nowadays some social and environmental MUPS. For the Dutch North Sea area there aren't yet comparable ongoing pilots, However right from the start of the single use pilot wind farms the environmental mpacts have been monitored. There are such positive impacts that e.g. NGO's are strongly in favour not to extend these single-use activities in multi-use business with possibly a detrimental impact. Even one is in favour of declaring the single use wind farms as a nature protective area.

For the North Sea site the following stakeholders are becoming increasingly involved: Dutch offshore wind energy the Dutch offshore wind industry is already active in this field for 40 years, however in operating near-shore wind farms only in the past 6 years. Around 150 companies in the Netherlands are active in offshore wind throughout the entire supply chain, ranging from blade production and hydrography up to foundation constructions and heavy logistics. It is well known that the Netherlands excels in foundations, installation work and logistics. Since a few years more companies are becoming active in the more far offshore large wind farms developments of which the Gemini project is the first one to be build in due time. The other two sites are still concessions off the coast of IJmuiden (1000MW; middle Netherlands) and Borsele (1000 MW; south Netherlands). By the year 2020 the Dutch Government aims to have installed 6000 MW of offshore wind energy capacity to reach its renewable energy goals. Only approximately 2000-3000 MW can be installed within 50-60 km distance from the shore, the remaining capacity will have to be installed further away, far offshore with water depths of more than 30 meters with larger challenges, installation and operation/maintenance of a wind farm.

Dutch offshore aquaculture (fishcages, shellfish, sea weed)

On the contrary with the Dutch offshore wind, this sector is at the beginning of a new development. For example the shellfish companies are in a transition phase, from inshore blue mussel cultures to more offshore cultures. Because of the shallow waters off the coast of the Netherlands no companies are interested yet in fish cage cultures. Regarding seaweed large volumes are already being imported by Dutch companies from Asia and France for a very competitive price. And only on a very small pilot scale some experiments are being conducted by research institutes and universities, see Table 2.2.6. Once a large scale North Sea seaweed business case has been drafted, then maybe some companies are interested as well. Although North Sea proven installations have still to be designed and offshore tested in the coming years before one can ever think of any multi-use activities in/near wind farms. An expected timeframe is 5 – 10 years.

Table 2.2.6 – Several initiatives of offshore aquaculture in The Netherlands.

Dutch offshore aquaculture	**status**
Fish cages 	Dutch continental shelf too shallow (abt 30 m)
Bluemussel cultures 	Start in 2013 with pilot mussel seed collectors near-shore (Voor-Delta) (6 x 25 ha)
Seaweed 	Small-scale research pilot off the coast of Texel and in the EasterSchelde Estuary

Fisheries

Already from the start of the planning and building of the two Dutch wind farms out in the sea, the Egmond aan Zee Offshore wind Farm (108 MW, NUON, shell, 2006) and Princes Amalia wind farm (120 MW; Eneco, Econcern, 2008) and fishermen (organizations) are discussing either compensation fees for lost of their fishing grounds and/or additional employment for their fishing vessels, e.g. fishing with static gears and sailing with tourists in/around the farms. Also the Dutch North Sea fisheries are in a transition phase to more sustainability. Through the Masterplan Sustainable Fisheries new fishing boat designs have been drafted with multipurpose possibilities for service and maintenance work in wind farms.
Since 2011 these MUP discussions have been further structured under the umbrella of some fishermen organizations with governmental and offshore wind parties.

Multi-use and economics

From 2012 onwards, offshore wind is no longer eligible for subsidy under the SDE+ program. It is argued that offshore wind is too expensive – compared to other production methods – and focus should first be on innovation, reducing cost price. This is one of the reasons that the single users are becoming interested in sharing infrastructures decreasing the Operation and maintenance costs (O&M).

Besides there is no common framework to discuss and assess the risks associated with third-party access. This increases uncertainty. It also explains recurring discussions on the insurance of MUPs. Current practice of regulators is to forbid third-party access to the offshore wind parks. Differing insights between policy-makers and regulators can be an obstacle to further development.

Multi-use and Social considerations

In Dutch policies, multi-use platforms are mentioned as a promising way to make the most out of scarce available space (Ministries of V&W, VROM en LNV, 2009). Till 2012 there was no“demand” for multi-use platforms, there are no companies who want to construct them yet. Energy companies have and will built various small scale offshore wind parks but integration with other functions is not desired. The offshore aquaculture sector is small – focusing only on mussels. Consequently, policy-makers and regulators have not been challenged to handle request for permits and a regulatory framework for MUPs is missing. Also, in the spatial plans for the North Sea, there is no area designated for aquaculture. However in the Dutch annotation Beleidsnota Noordzee 2009-2015, it is explicitly mentioned that co-use offshore wind energy parks, for example for recreation, fisheries and aquaculture, should be allowed as much as possible and needs to be discussed with the involved parties as the policy is implemented.

Multi-use and environmental considerations

In 2011 Rijkswaterstaat stated that smart uses of space could be a solution to the shortage of space on the North Sea (Verhaeghe et al, 2011). Aquaculture inside off shore windmill platforms was mentioned as a possible smart use of space, which leads to chances for clever entrepreneurship. However in the Integral Management plan for the North Sea (Integraal Beheerplan Noordzee, 2006) there is no space indicated for offshore aquaculture for the Dutch part of the North Sea. This means that aquaculture activities in wind energy platforms needs to get exemption, to be applied for trough permits. This framework exists of five tests: 1. Defining spatial claim, 2. Precaution, 3. Usefulness and need, 4. Location choice and spatial use and 5. Reducing the effect and compensation.

For new activities this means that developers have to reduce or prevent negative effects on the environment, which is tested using precautionary test. They have to address why it is important that this activity takes place in the North Sea using a social cost-benefit analyses. The space needed for the activity must be carefully chosen and sufficiently used and when the activity compromises important natural values these need to be compensated in another area.

Marine protein production in open water systems per definition interacts with the surrounding aquatic ecosystem. Whether and to what degree this affects ecological sustainability depends on the type of culture and the extent of integration between different culture types and other activities. Multi-Use Platforms at sea (MUPs) aim at optimal integration of activities, and each activity is thereby placed in a wider ecosystem context. The aim is to manage all activities in such way that it contributes to the sustainable development and equity of the whole. The foreseen MUPS production system combines a set of different production functions/chains, probably with mutual interactions between the individual functions.

2.3 The open deep water site, Atlantic Ocean

2.3.1 Short site description

The Cantabrian Offshore Site (COS), the open deep water site (Atlantic Ocean), is located in the north coast of Spain, in the region of Cantabria (see Figure 2.3.1). Close to the capital city of the region, Santander. It is a medium size site, its surface is 100km2. It has a rectangular shape between 3 and 20 km far from the shore line (see Figure 2).

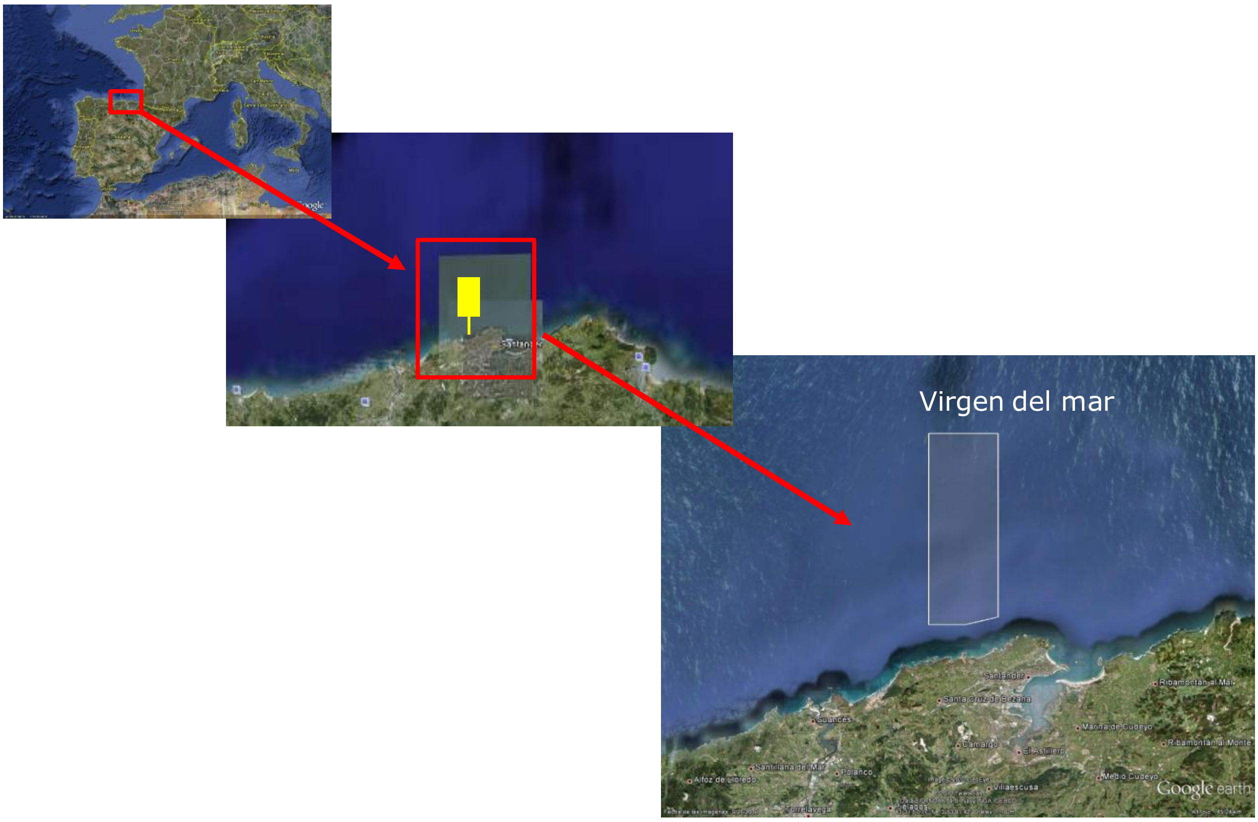


Figure 2.3.1 - Location of Cantabrian Offshore site (The open deep water site, Atlantic Ocean)

COS bathymetry varies between 50 and 250 m of water depth at 3km and 20km far from the shore line respectively. The bathymetry is in general smooth with some irregularities on the north-eastern part between 50 and 100m of water depth (see Figure 2.3.2).

Due to the water depth range, in this test site only floating concepts will be considered. These concepts are especially relevant in some countries like Spain where the continental shelf is narrow and offsite MUPs are only possible at large water depths. COS is in particular challenging because of the very rough wave and wind conditions.

The seabed observed in this area is a mix of sandy and rocky seabed, mostly limestone.

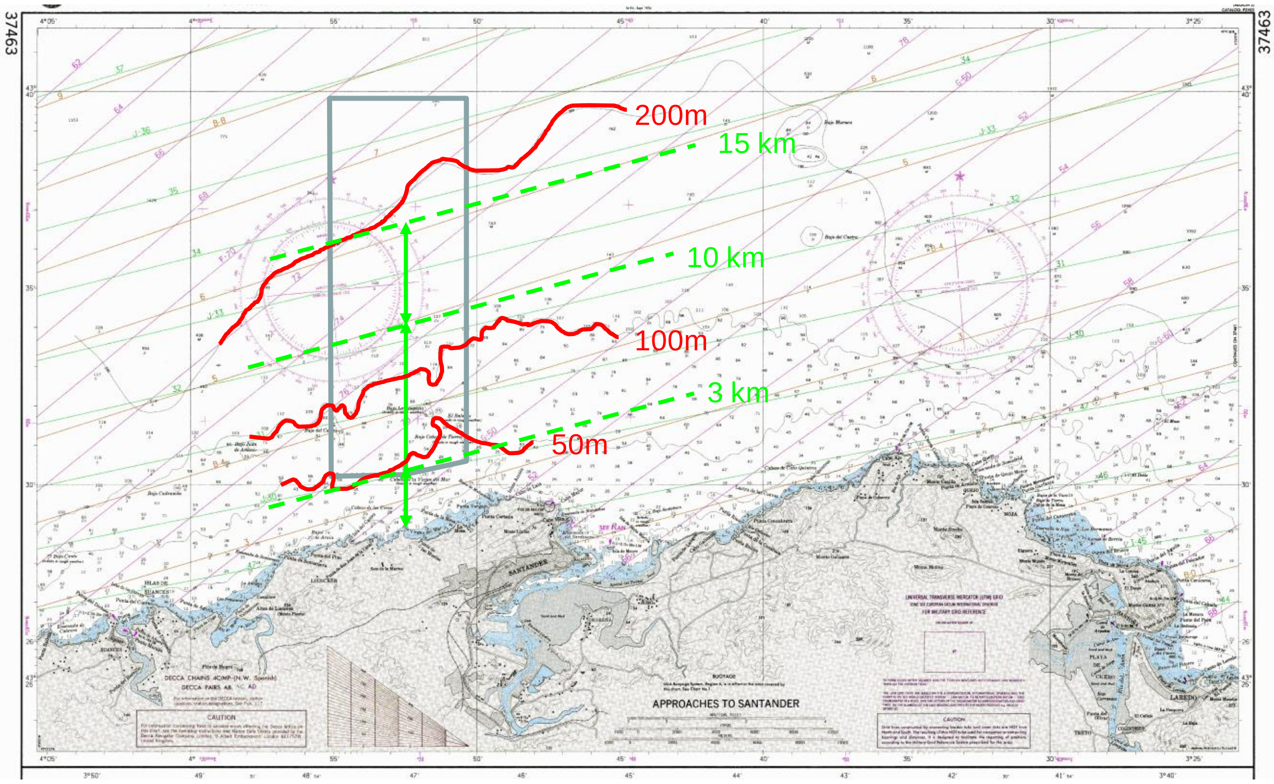


Figure 2.3.2 - COS Bathymetry and key distances

The Cantabrian Offshore Site is located, as it has been said, close to the capital city of Santander. The southern limit of COS is located approximately 7 km far from the city. Nevertheless the closest area is an unpopulated area with gravel and rocky beaches and small cliffs (see Figure 2.3.3). Thanks to the short distance to a main city, COS has available significant facilities and infrastructures. Among them is important to highlight the harbour, where a very active shipyard is already located. As well as the communications facilities (train, motorway and airport), thanks to them COS can be considered a well communicated site.

Figure 2.3.3 - Cantabrian Offshore Site Shoreline

On Figure 2.3.4 the Marine Renewables Zonning, developed by the Ministry of Industry, is shown. From it we can conclude that COS is located on a suitable area. The most important restriction observed nearby the site is the harbor as well as small areas of special interest from the environmental point of view. All of them located close to the shoreline or at the entrance of the bay of Santander.

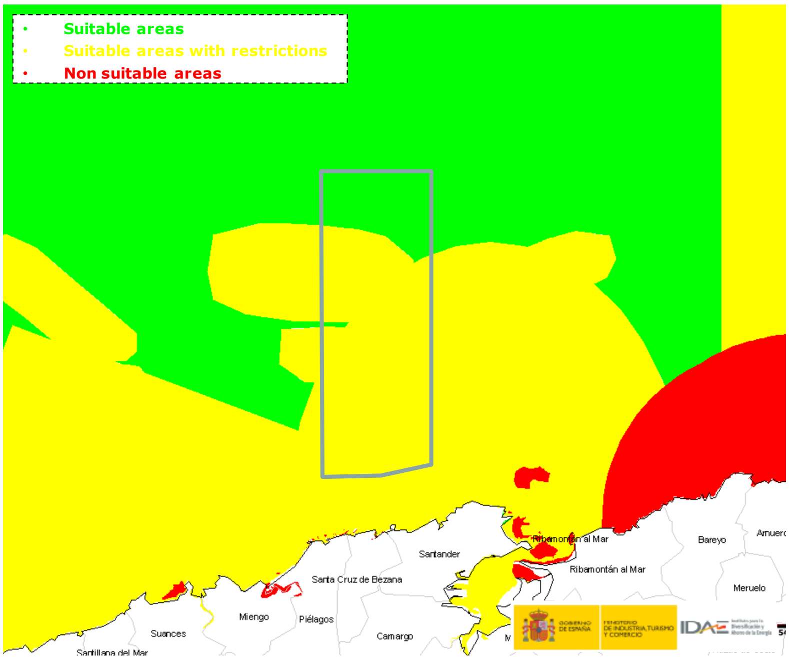


Figure 2.3.4. Spatial zoning of Santander Maritime Area from the Marine Renewables Implementation

The site is already monitorized by private and public initiatives. The Government of Cantabria deployed on 2009 a measurement buoy (www.redvigia.es) at 40m of water depth which is located at hundreds of meters south of the southern limit of COS (see Figure 2.3.5). It measures waves, currents and wind, as well as other ocean parameters like temperature and contaminants. The IEO (Spanish Institute of Oceanography), deployed a wave buoy (http://www.boya_agl.st.ieo.es/boya_agl) on 2007. It is located, 35 km north from the shoreline and at very deep waters and focused on wave parameters.

On the other hand, there is a private initiative called Idermar (www.idermar.es), which is a regional company focused on the development of floating met mast. It has developed three different floating met mast prototype, two of them are delployed on the COS (see Figure 2.3.5). Both devices are focused on wind measurements, the oldest one deployed on May 2009 measures wind up to 65m of high. While the newest one has been deployed on October 2011 and it measures wind at five measuring point between 20 and 90m height (Figure 2.3.6). Idermar floating met masts are concepts already design and conceptualized in order to provide reliable data in deep and very deep waters. Those data are mainly focused on the offshore wind industry.

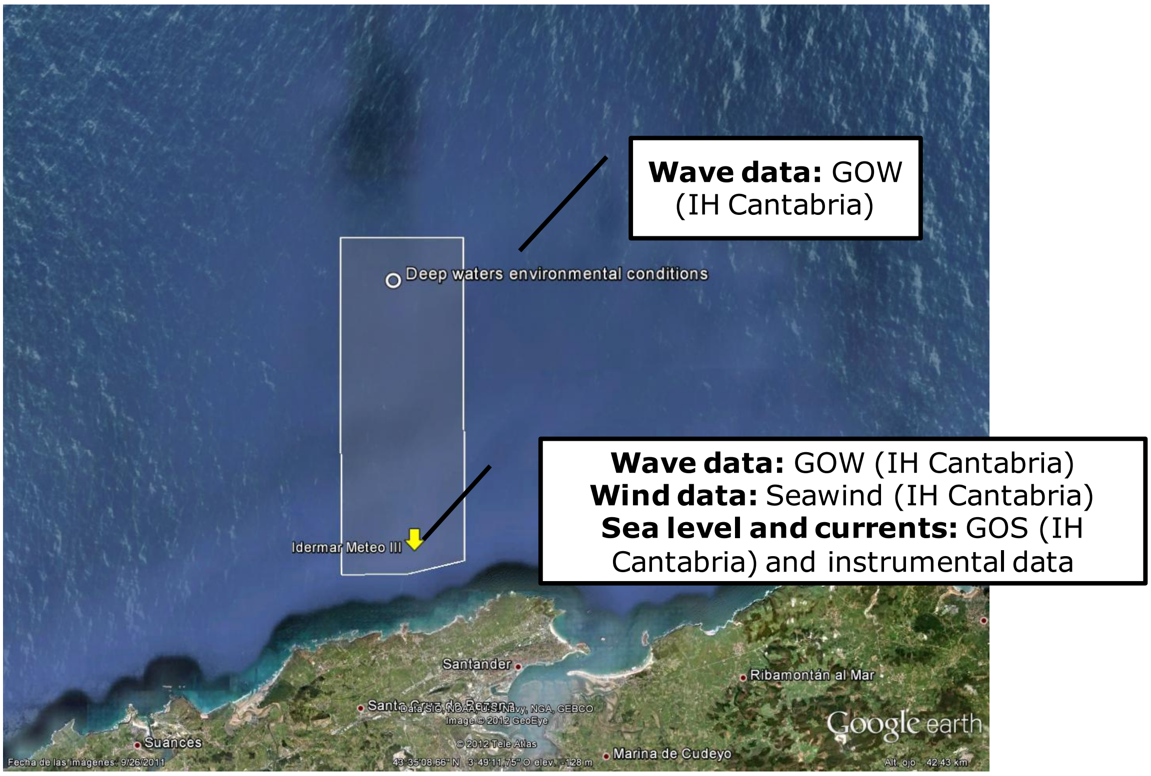


Figure 2.3.5. Cantabrian Offshore Site existing monitoring system

Figure 2.3.6. Idermar floating met mast at Cantabrian Offshore Site

2.3.2 Current policy, management and planning strategies

Regulatory Framework for the development of Marine Energy in Spain main items are:

1. Renewable Energies in Spain: General Framework.
2. Royal Decree No. 661/2007
3. Royal Decree No. 1028/2007.
4. Administrative Procedures.

Renewable Energies in Spain: General framework

Renewable Energies Plan 2011-2020 (PER)

The Spanish Renewable Energies Plan (PER) has been approved the 11th of November of 2011. The main objective of this plan is to establish a set of guidelines and policies to meet European objectives by 2020 given by the EU Directive 2009/28/CE. This directive has been approved the 23rd of April of 2009. The PER promotes the production of renewable energies according to the Royal Decree 661/207 and the Sustainable Economy Law 2/2011 approved the 4th of March of 2011.

The PER establishes the available power of each marine energy. By 2020, Offshore wind energy goals 750MW while wave energy power goal is 100MW.

Renewable energies moratorium: New power plants developments

The 27th of January of 2012, because of the new economic perspectives of Spain, the Government approved the Royal Decree 1/2012. It sets a renewable energies moratorium which paralyzes the feed in tariff framework given by the PER for new renewable technologies.

Royal Decree No. 661/2007, Special Regime

Previously to PER 2011-2020 there was a renewable energies plan (PER 2005-2010), which was developed to promote and regulate renewable energies development. The Royal Decree 661/2007 was approved to meet PER 2005-2010 renewable energies objectives. It establishes a regular and legal framework in order to give stability and certainty and a sufficient return to the society.

One of its main aims is to try to promote an efficient operation of the electrical system as well as integrates and maximizes renewable energies in the electrical system. Finally, it establishes some mechanism and incentives for market participation.

The Royal Decree 661/2007 classifies the different kinds of energy resources and marine energies, including wind and waves, are included on the Category b) renewable. Therefore, they are considered special regime energy resources. They must be included in the special regime following the procedure explained on Figure 2.3.7.

When the installation is located in territorial waters the Regional Government or General State Administration (Directorate-General of Energy Policy and Mines) is entitled to include new developments in the special legal regime.

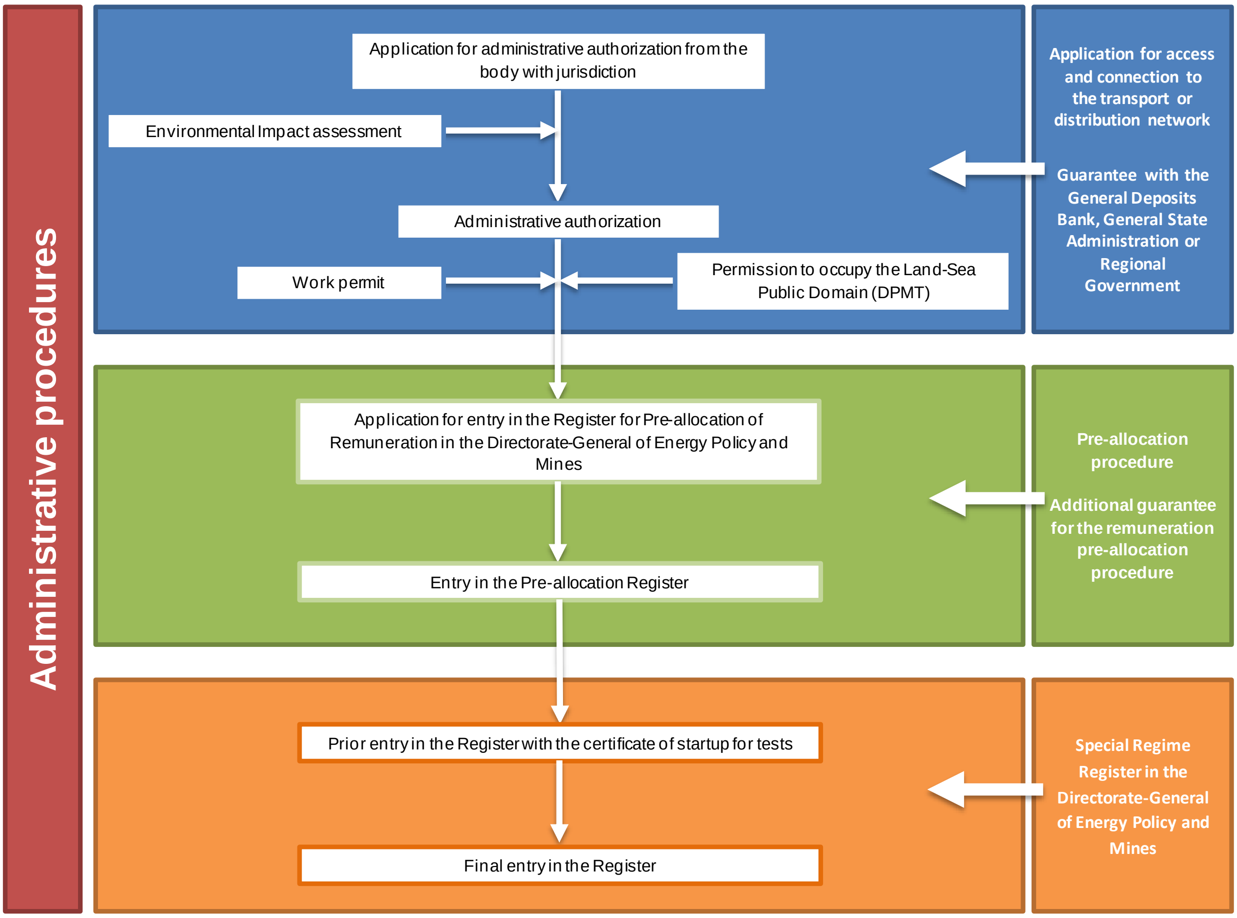


Figure 2.3.7. Royal Decree No. 661/2007, Special Regime. Administrative procedure.

Once the administrative procedure is successfully finished, the wind/wave energy producer has the following rights and obligations:

Rights:

- To connect to the electrical network.
- To transfer its net electrical energy production to the system.
- To receive the remuneration according to the Royal Decree.
- To sell all or part of the energy.
- Priority in access and connection to the network.

Obligations:

- To deliver the energy in adequate technical conditions.
- To associate with a generation control center which will act as interlocutor with the Transmission System Operator (TSO) for installations with power greater than 10 MW.
- To send an annual report-summary to the body with jurisdiction.

The updated remuneration rates of renewable energies can be consulted at: http://www.minetur.gob.es/energia/electricidad/Tarifas/Tarifas2008/Revisiones2012/OrdenIET3586_2011.pdf.

Royal Decree No. 1028/2007 on marine installations for electricity production

The objective of the present royal decree is to set a procedure for the authorization of electrical generating installations in territorial waters. It provides differentiated competitive procedure for wind installations of more than 50 MW power.

The procedure begins with application for an administrative authorization for marine non-wind facilities. Therefore, it distinguishes between wind offshore energy and other marine renewable energies.

A subsidiary procedure contained in Royal Decree No. 1955/2000 of December 1 regulating transport, distribution, commercialization, supply and authorization procedures for electrical energy installations must be fulfilled.
Figure 2.3.8 shows Royal Decree 1028/2007 administrative procedure.

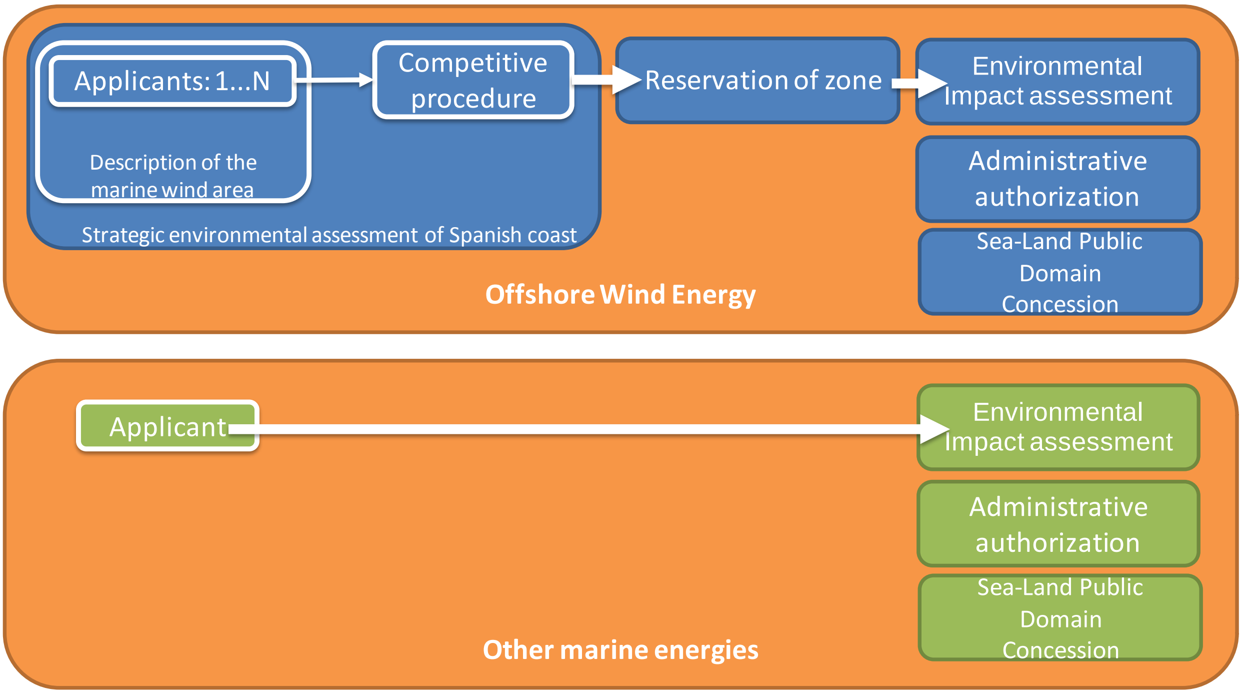


Figure 2.3.8. Royal Decree 1028/2007 procedure

The following administrations are involved and have jurisdiction on this procedure:

- Ministry of Industry, Energy and Tourism. (Directorate-General of Energy Policy and Mines). The decision-making body. Administrative authorization of installations.
- Ministry of Agriculture, Food, and the Environment (Directorate-General of Coast and Sea Sustainability). Grants authorizations and concessions to occupy the sea-land public domain.
- Ministry of Agriculture, Food, and the Environment. (Directorate-General of Environmental Quality and Assessment and Natural Affairs). An environmental body.
- Ministry of Agriculture, Food, and the Environment. (Secretariat-General for the Sea). Passes measures to protect and regenerate fishery resources.

- Ministry of Development, (Directorate-General of the Merchant Marine). Passes measures for maritime security, navigation and human life at sea.
- Port authority. Grants authorizations and concessions to occupy the port public domain.

These jurisdictions apply even though they may be legally assigned to other bodies in the Administration.

Administrative procedures

The administrative procedures have to fulfill the criteria established by Part VII of Royal Decree No. 1955/2000. A summary of the articles and sections that must be accomplished is given next:

Chapter II. Authorizations for the construction, modification, enlargement and operation of installations.

Article 115. The authorization requirement.
Article 120. Application for authorization.
Article 121. Applicant's capacity.

Section I. Administrative authorization.

Article 122. Filing the application for administrative authorization.
Article 123. Content of the application for administrative authorization.
Article 124. Formalities for assessment of the environmental impact.
Article 125. Public consultation.
Article 126. Pleas.
Article 127. Informing other Public Administrations.
Article 128. Resolution.
Article 129. Occupation of the sea-land public domain.

Section II. Approval of the project.

Article 130. Application.
Article 131. Conditioning factors and project approval.

Section III. Authorization to operate.

Article 132. Certificate of startup.

A complete diagram of the administrative procedure is available at:
http://www.minetur.gob.es/energia/electricidad/TramitacionInstalaciones/Documents/CuadroProcedimientoAutorizacionesrevOct08.pdf

Administrative Authorization

The authorization procedure is set by the Royal Decree No. 1955/2000 of 1 December regulating transport, distribution, commercialization, supply and procedures for the authorization of electrical energy installations.

Environmental Impact Assessment of the Project

The Environmental Impact Assessment must fulfill the requirements set by: Legislative Royal Decree No. 1/2008 of January 11 passing the Reform Act for the Environmental Impact Assessment of projects. This LRD was modified by the Law 6/2010 of March 24.

Environmental Assessment of the Project. The Environmental Impact Study

The scope and the level of detail are defined in advance by the environmental body. The minimum content of the study is:

- General description of the proposed project, including information on its site, design, size, use of the land and other natural resources. An estimate by type and quantity of the expected residues and emissions (including water, air and soil pollution, noise, vibration, light, heat and radiation) resulting from the operation of the proposed development.
- The data required to identify and asses the main effects that the proposed development is likely to have on the environment,
- An outline of the main alternatives studied by the developer and an indication of the main reasons for his or her choice taking into account the effects on the environment,
- A description of the aspects of the environment likely to be particularly affected by the proposed development including:
    - Human beings, fauna and flora,
    - Soil, water, air, climatic factors and the landscape,
    - Material assets including the architectural, archaeological and cultural heritage.

A description of the likely significant effects, (direct, indirect, secondary, cumulative, short medium and long term, permanent and temporary, positive and negative) of the proposed development resulting from (a) its existence, (b) the use of natural resources and (c) the emission of pollutants, creation of nuisances and elimination of waste and the forecasting methods used to assess the impact on the environment.

Occupation of the Sea-Land Public Domain.

The occupation of the Sea-Land is regulated by the Article 146 and the following articles of Royal Decree No. 1471/1989 of December 1 passing the General Regulation for Development and Implementation of the Coasts Act, Act No. 22/1988 of July 28.
Documentation required:

- Identification of the Sea-Land Public Domain to be occupied.
- Justification of the need to occupy the Sea-Land Public Domain.
- The basic design or construction project.
- An economic-financial study.
- A receipt for payment of the provisional bond.
- A basic study of the coastal dynamic (with the content established in Article 92 of the Coasts Act Regulations).
- An environmental impact study.
- Maximum term, 30 years.

Approval of the construction project.

Application must be presented to the Division or as applicable the Office of Industry and Energy of the Government Delegations or Sub-Delegations in the provinces affected, accompanied by the construction project and the offprint of those parts of the project which affect other Administrations.

Startup certificate (APS).

Application must be presented along with the end of work certificate in the Division or as applicable in the Industry and Energy Office in each Government Delegation or Sub-Delegation.

The Startup Certificate is drawn up by the provincial authority following the necessary technical checks. A Startup Certificate may be drawn up for tests, at the request of the installation's owner.

2.3.3 Metocean conditions and renewable energy potential

Wave conditions

60 yrs of hourly sea state parameters (described in WP/Report 3.1) at the Cantabrian Sea study case have been analyze to characterize the wave conditions and wave energy power.

Figure 2.3.9 shows the seasonal behaviour of significant wave height, peak period and mean wave direction for the whole empirical distribution. The seasonal patterns of wave height and peak period show a clear winter-summer pattern and powered winter season. Lower wave heights and peak periods occur on June, July and August. Northwest is the dominant mean wave direction.

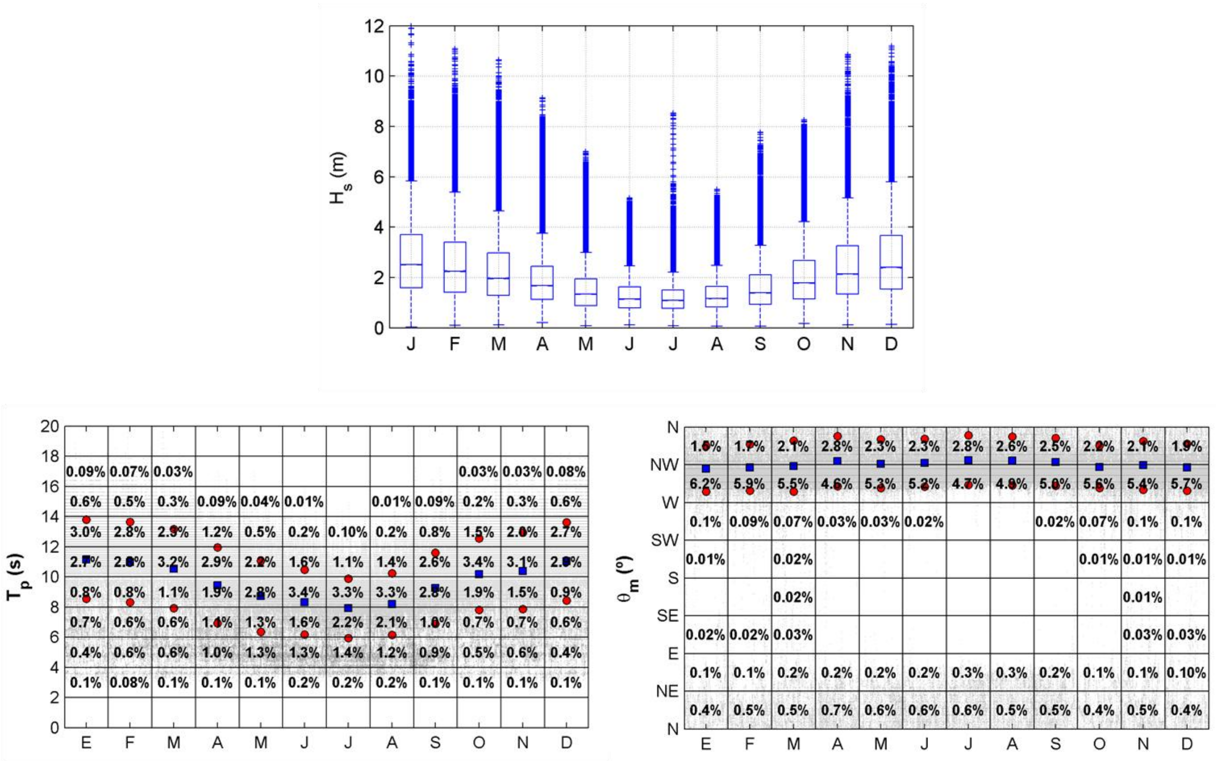


Figure 2.3.9 - Seasonal behavior of significant wave height, peak period and mean wave direction at Cantabrian Offshore Site (▪ μ • μ ± σ)

Figure 2.3.10 shows directional and probability roses and polar quantile plot of significant wave height and peak period. Wave heights higher than 4 meters and peak periods higher than 12 s can be only detected from the Northwest dominant direction.
The joint probability distributions of significant wave height vs. peak period and wave height vs. mean wave direction are shown in Figure 2.3.11. High probability corresponds to lower than 6 meters wave heights and peak periods between 4 and 14 s.

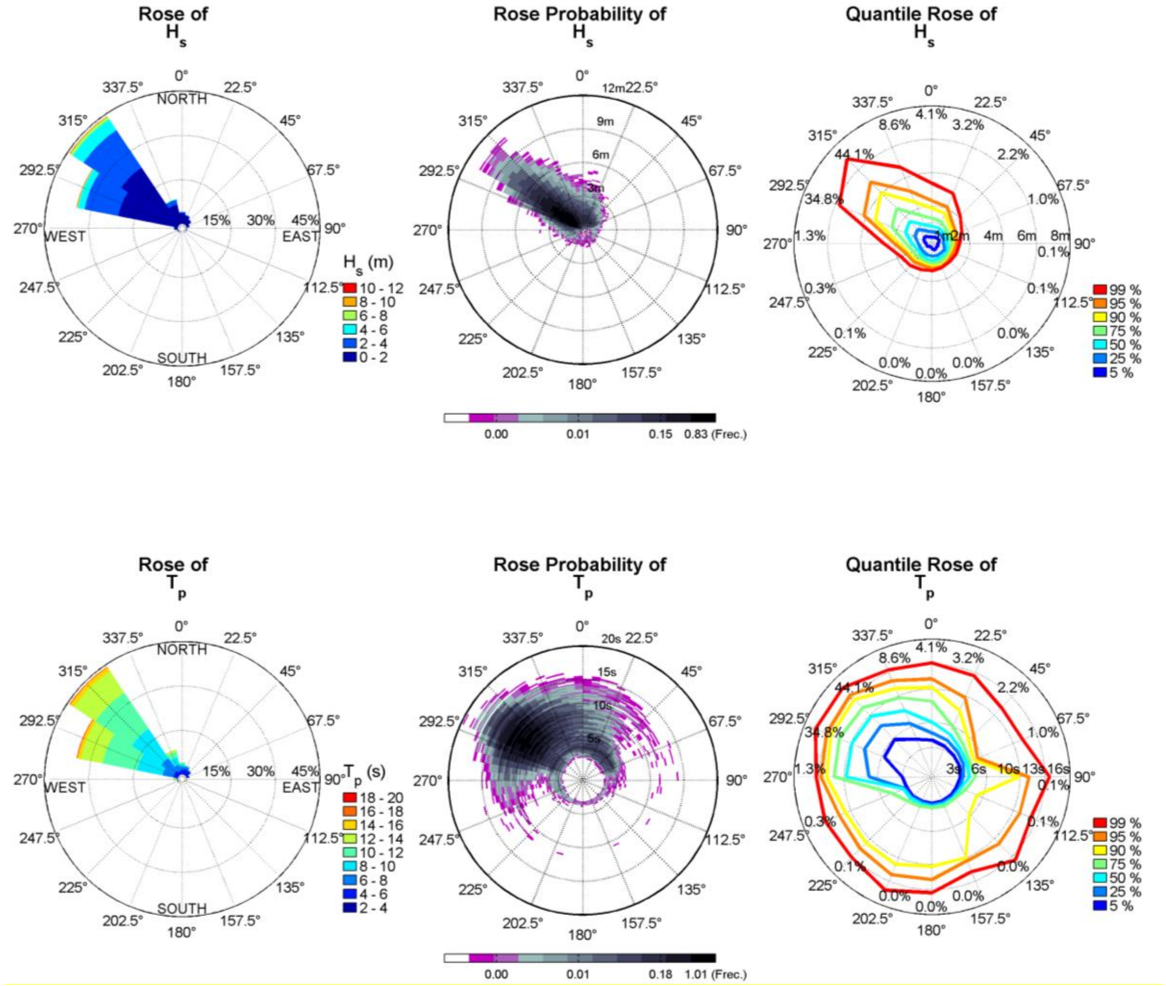


Figure 2.3.10 Directional and probability roses and polar quantile plot of significant wave height and peak period at Cantabrian Offshore Site

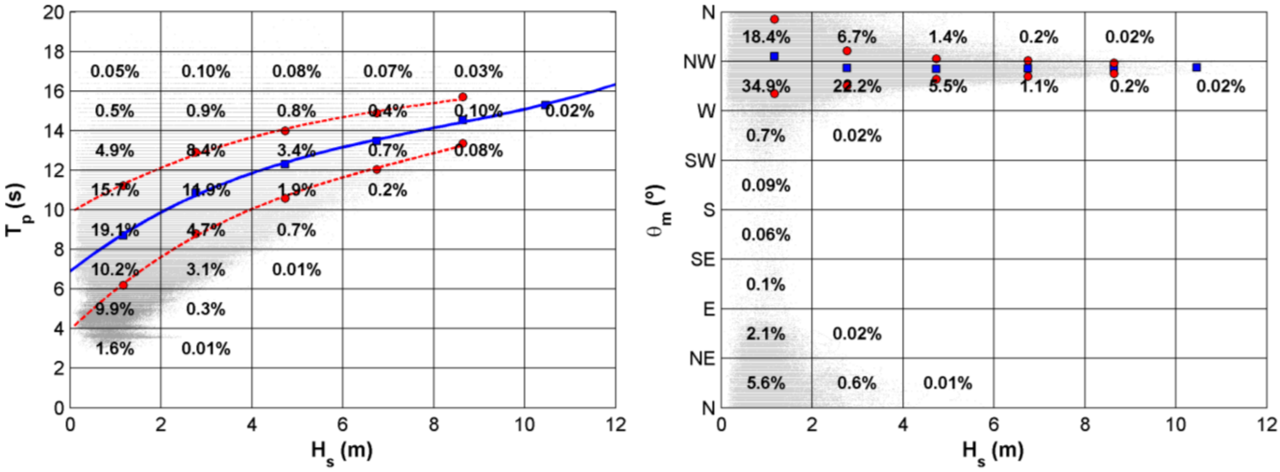


Figure 2.3.11 Joint probability distributions of significant wave height vs. peak period and wave height vs. mean wave direction

Figure 2.3.12 shows the mean number of events/yr exceeded per wave height magnitude. Major of the events exceed 2 m and less than 20 events per year exceed 4 meters.
The assessment of values associated to return periods is required for survivability analysis and structural design. An extreme value model based on exceedance over a threshold (99.5% percentile) has been applied. The peaks over threshold are fitted to the Pareto distribution and the return values estimated in terms of GEV distribution. A significant wave height of 11 meters is associated to an averaged recurrence interval of 50 yr return period.
The extreme analysis of the monthly maxima shows lower return values in summer. The extreme analysis applied for several directional sectors indicates larger return values of waves from Northwest.
The mean wave power is about 33Kw/m for the dominant NW and WNW (figure Figure 2.3.14), with higher power during winter season.

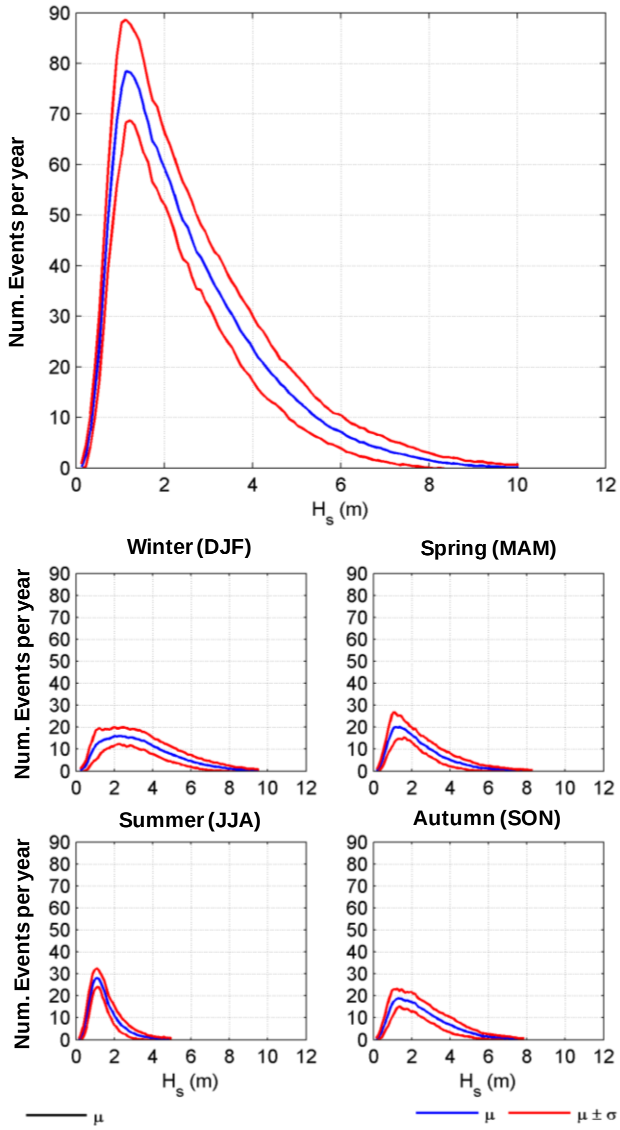


Figure 2.3.12 Mean number of events/yr exceeded per wave height magnitude at Cantabrian Offshore Site

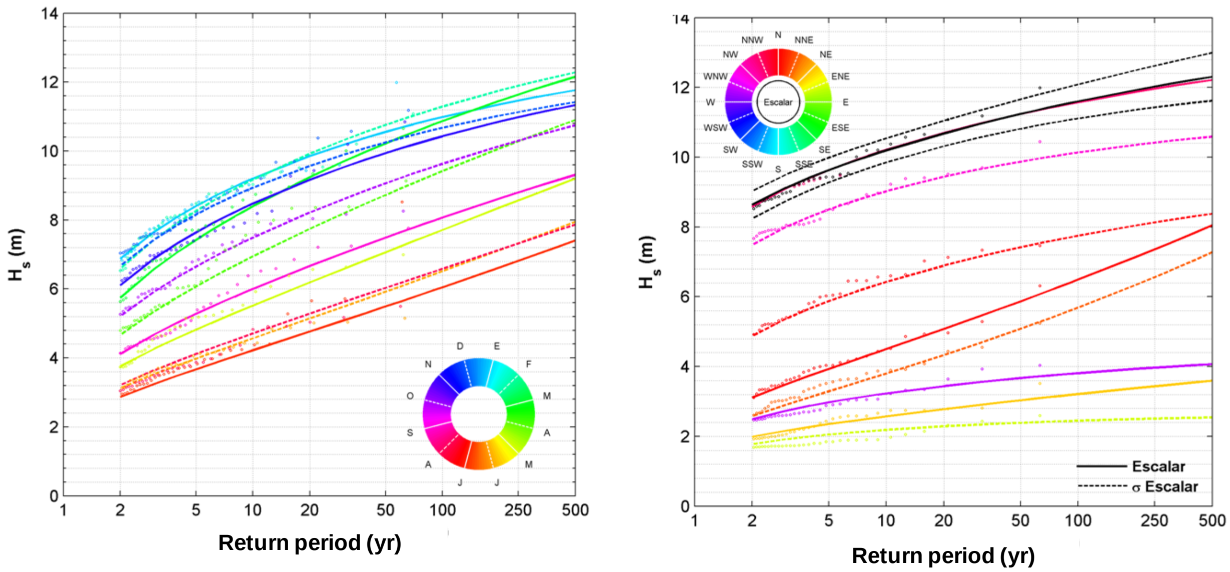


Figure 2.3.13 Return period of significant wave height at COS . (a) Seasonal analysis. (b) Mean wave direction analysis

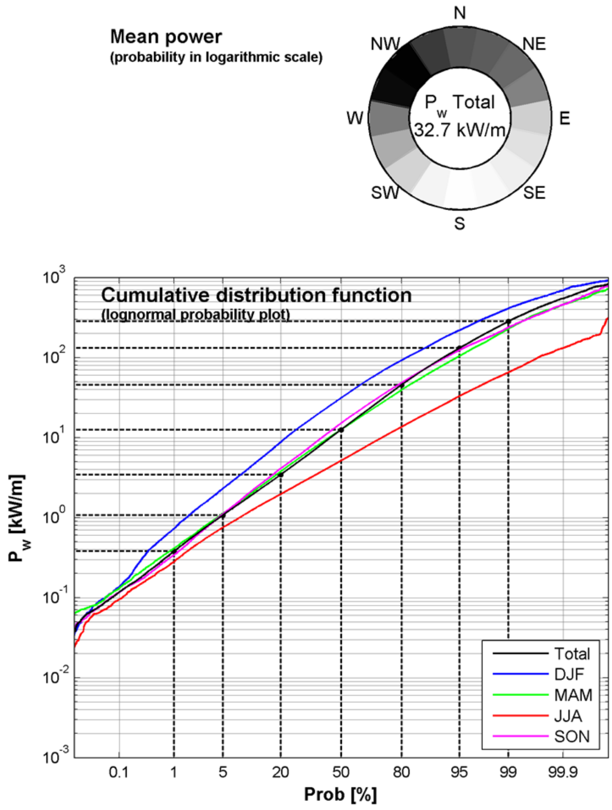


Figure 2.3.14 Mean wave power at Cantabrian Offshore Site

Current conditions

Tidal currents time series at the Atlantic study site are shown in Figure 2.3.15. Maximum values almost reach 1.5 cm/s.

Figure 2.3.16 indicates that the 50% of the data barely exceed 0.5 cm/s. magnitudes above 1 cm/s have an occurrence rate of 20%. Figure 2.3.17 shows that there are only two main directions in the tidal propagation: WNW and ESE. Other directions have not only a low occurrence probability but also a small magnitude.

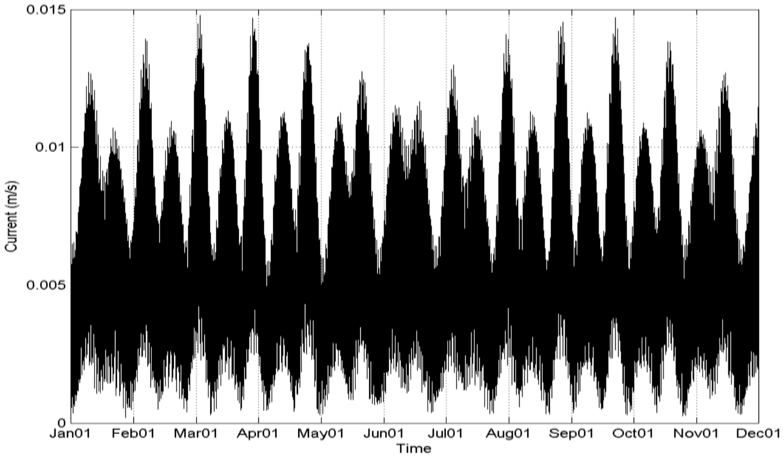


Figure 2.3.15 Tidal current time series at Atlantic study site

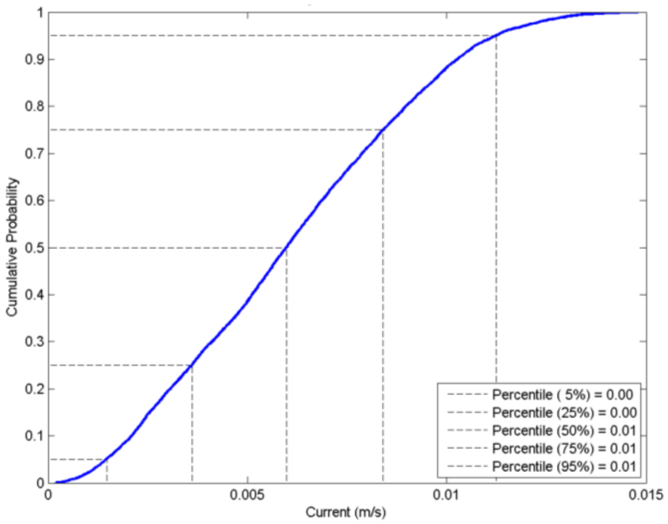


Figure 2.3.16 Tidal current PDF

The general equation for power available from tidal currents is given by:

$$P_{cross-section} = \frac{1}{2}\rho \cdot U^3$$

ρ is the density of water (1027 kg/m3)

U is the instantaneous current velocity (m/s)

Therefore, results are depicted for a one square metre cross sectional area. Figure 2.3.18 shows that values at the study area are smaller than 0.1 W/m2.

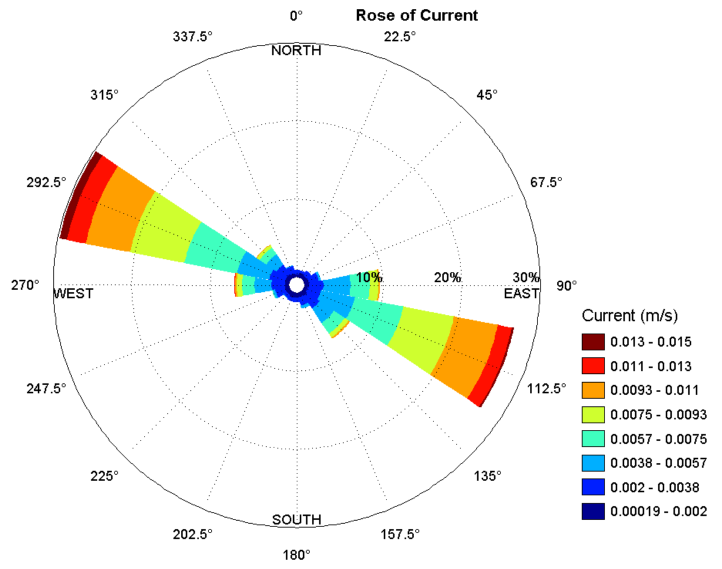


Figure 2.3.17 Rose of tidal current for the Atlantic study site

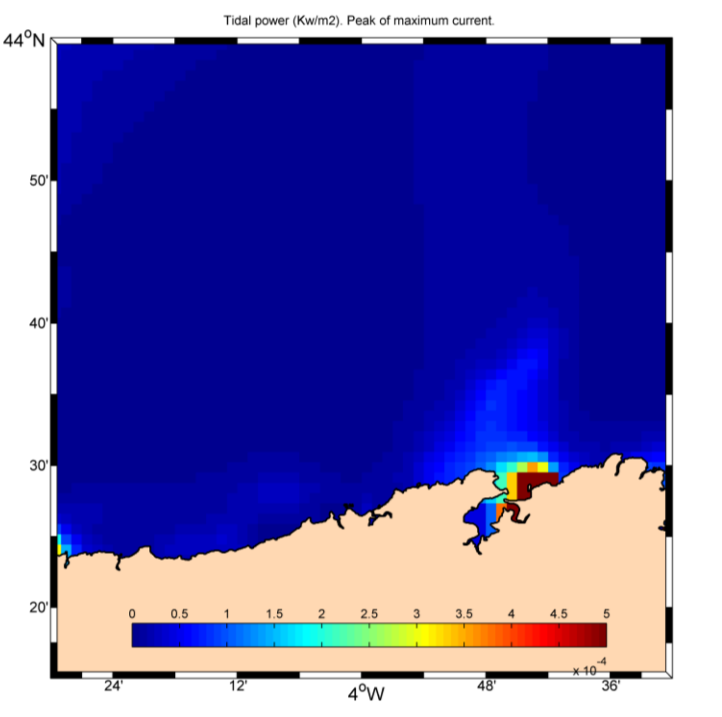


Figure 2.3.18. Peak of spring tidal power (Kw/m2)

2.3.4 **Hydromorphological analysis**

The Atlantic Study Site is located on close to the Bay of Biscay (see red rectangle in Figure 2.3.19). The Bay of Biscay is located in the northeast Atlantic Ocean, along the western coast of France. Traditionally, it lies along the northern coast of Spain west to Cape Ortegal.

The geographical setting of the southeastern Bay is characterised by the orientation of the coast: east-west along the Spanish coast and north-south along the French coast. The submarine topography is complex in the area. Below a water depth of 4,500 m, there is an abyssal plain, which constitutes the oceanic section of the Bay. Beyond 200 m water depth, the transition between the deep sea and the continental shelf occurs. The continental slope is steep (10 to 30%), with submarine canyons, and it is formed by the Armorican, Aquitaine and Cantabrian continental slopes (Pascual et al., 2004).

Bordering the slope appears the continental shelf (water depths of less than 200 m). In the northern part, the Armorican shelf has a mean width of about 150-180 km and a length of 300 km. In southern part, the Aquitaine shelf has a width varying from 50 to 150 km and a mean length of 260 km. The Cantabrian shelf, oriented east-west, is extremely narrow with a mean width of 30 to 40 km (Koutsikopoulos and Le Cann, 1996; Lavín et al., 2006).

The mean tidal range is approximately 1.5 m on neap tides and 4 m on springs along the Cantabrian coast. The maximum annual range exceeds 4.5 m (Instituto Hidrográfico de la Marina, 1992) during equinoctial tides in March and September.

The currents patterns on the Cantabrian Sea are strongly influenced by the dramatic changes on the bathymetry. The oceanic surface circulation over the abyssal plain is particularly slack and it is characterised by weak anticyclonic circulation (at about 1-2 cm s-1) (Koutsikopoulos and Le Cann, 1996). Although weak, the surface currents over the deep basin vary according to the seasonal wind regime. Along the continental slope appears the Iberian Poleward Current (IPC). It enters the Bay of Biscay around Cape Finisterre (NW Spain). It is warm and salty water which flows eastward along the Cantabrian continental slope. Over the Cantabrian slope, the IPC reaches its maximum from October to February and it experiences considerable variations in magnitude from year to year (Gil, 2003). Finally, the shelf currents, where the Cantabrian Offshore Site is, are the combined effect of the wind, tides and water density (Lazure, 1997). The Bay of Biscay shelf is dominated by semidiurnal tidal currents, with diurnal currents being very weak. These currents are usually amplified by the topography and the width of the shelf. Neverthelles, the tidal currents are weaker, at less than 15 cm s-1 (Le Cann, 1990) and the water mass circulation is governed principally by wind-induced and, to a lesser extent, by density currents (Puillat et al., 2004; Puillat et al., 2006).

The seabed at the Cantabrian Offshore Site is composed by rocks and sand. Some areas are dominated by rocks, others are dominated by sands and there are several transition zones. However due to the large water depth at the site, it will not be expected significative sediment transport.

The next figures show the typical sea bed observed southern limit of the site (see Figure 2.3.20 and Figure 2.3.21). Both figures show two different examples of observed seabed. On figure shows a Small rocks composed seabed and the second one a purely rocky seabed.

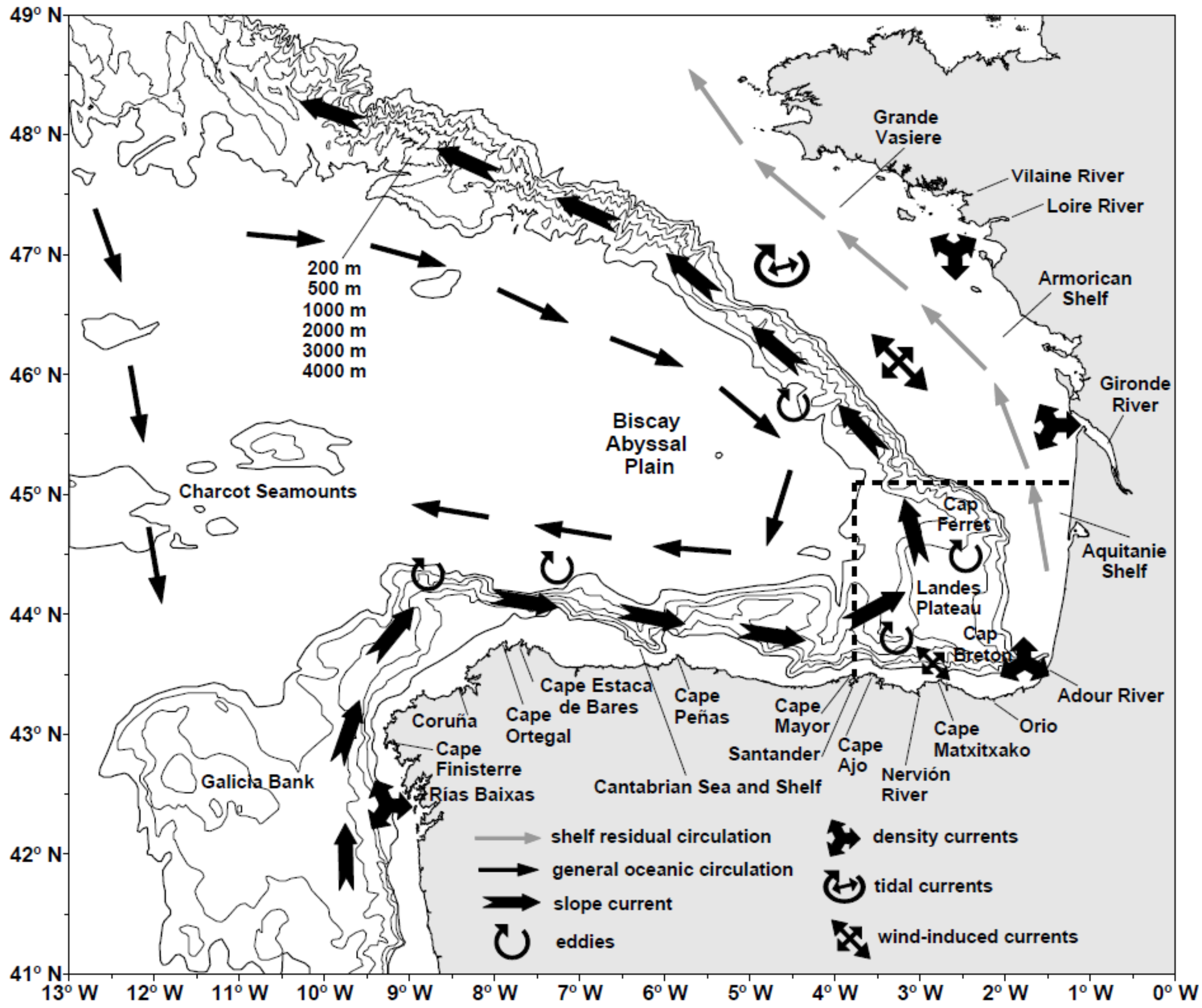


Figure 2.3.19. The main features of the water circulation within the Bay of Biscay.
Ferrer et al., 2009

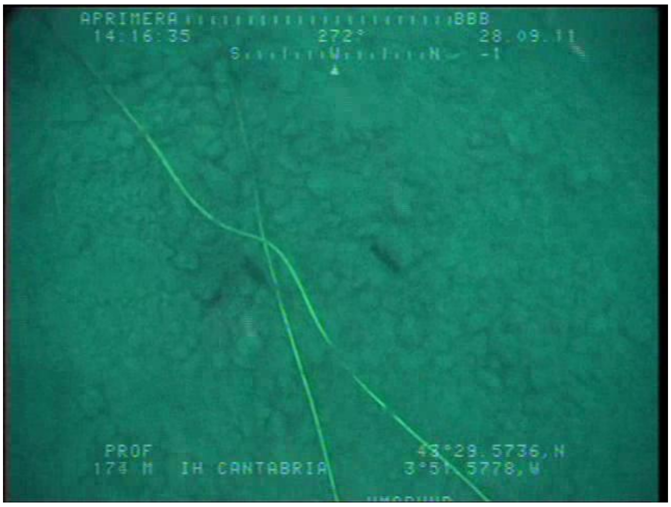


Figure 2.3.20 Smalls rocks observed at the southern limit of the site.
Photographs courtesy of Idermar

Figure 2.3.21 Rocky seabed observed at the southern limit of the site.
Photographs courtesy of Idermar

2.3.5 **Environmental characterisation**

Oceanographic and water masses conditions

Coastal waters in the Bay of Biscay are characterized by strong surface currents (1.2 m s_1) that flow eastward in summer and westward in winter, deep currents that flow oppositely, and strong winds throughout the year that prevent stratification in the water column.

In general terms, coastal waters in the Cantabric Sea are poor in nutrients, being nitrates the limiting factor for primary production in many situations. This coastal waters are well oxygenated, although oxygen concentration diminish with depth, reaching a minimum value at 500 - 1000 m. Studies carried out in the continental shelf waters off Santander (Lavin et al, 1999) showed that temperature follows the characteristic seasonal warming and cooling pattern, which determines a seasonal process of stratification and mixing of the water column The stratification period occurs annually between May and October in a layer of about 50 m depth. In the period between November and April the water column remained mixed. During spring and summer low salinity values were found in the surface due to continental runoff and advection from oceanic waters. In late autumn and winter, the salinity pattern was governed by an influx of salty water associated with the poleward current. As in other temperate latitudes, nitrates showed the highest values in winter throughout the water column and the lowest values at the surface during the stratified period. Wind-induced upwelling events were observed mainly in summer, which are characterized by low temperatures (< 12 ºC), high salinity and nutrient concentrations (Lavin et al, 1999).

Phytoplankton communities

The annual cycle of phytoplankton in the Cantabrian Sea shows the typical pattern of a temperate sea, with some peculiarities (Varela, 1996):

- Winter mixing, characterized by low biomass and production of phytoplankton, due to the low temperature and irradiance levels.
- Spring bloom, season with the maximum productivity.
- Summer stratification, when phytoplankton growth exhausts nutrients, and so biomass becomes very low. The thermocline acts as a physical barrier for the interchange with deep waters.
- Autumn mixing, when the water column mixes thoroughly and nutrients go upwards to the surface, allowing the formation of a smaller phytoplankton bloom.

In the Cantabrian waters phytoplankton biomass ranges from 15 mg m-2 (winter) to 70 mg m-2 (in spring), while in summer ranges from 35 mg m-2 (stratification phase) to 60 mg m-2 (upwelling).

The annual cycle of zooplankton abundance and biomass in the region presents a marked seasonality, with a main maximum in spring, corresponding to the growth of phytoplankton, although sometimes later, and secondary maximum in summer and autumn (Bode et al., 2009).

Seagrasses and macroalgae benthic communities

There are not seagrasses meadows in coastal areas of Cantabric sea, being restricted to estuaries. The growth of macroalgae is limited to shallow waters (about -25 m). In shallower rocky bottoms of Cantabrian coasts Gelidium corneum and Cystoseira baccata are the dominant species, due to their extensive distribution and high abundance (Guinda et al., 2012). The first one is more abundant in shallower waters and tends to decrease with depth, while the second one remains more or less constant from 5 to 22 m depth. There was also a great abundance of Laminaria ochroleuca and

Saccorhiza polyschides, which indicates the transitional character between cold and warm temperate coastal areas (Lüning, 1990), although a recent noteworthy regression of these species has been observed to the west.

Macroinvertebrates benthic communities

Infralittoral rocky bottoms

Regarding the fauna colonizing shallow rocky bottoms, sampling surveys carried out at about 35 m depth in front of Virgen del Mar identified species assemblages dwelling representative of benthic communities of exposed sublittoral rocky substrates (Echavarri-Erasun et al., 2007). These were arranged in small patches distributed in a heterogeneous way, indicating a complex mosaic distributional pattern. As a singularity, a high abundance of the tube-building Sabellaria spp was detected in the area.

Circalittoral rocky bottom

The main habitats described in the circalittoral bottoms are (MAGRAMA, 2012):

- Circalittoral cliffs colonized by a rich community of sessile or sedentary organisms (Porifera, hydroids, Anthozoa, sea cucumbers, etc..). One of the most characteristic species is Ophioderma longicauda.
- Steep rocky shoals, more than 50-60 meters deep, with a wide variety of species of encrusting, colonial, solitary, sessile and vagile invertebrates (Porifera, hydrozoans, Anthozoa, molluscs, polychaetes, crustaceans, bryozoans, echinoderms, ascidiáceos, etc..). The madreporian Dendrophyllia cornigera is present.
- Sponges communities in the deep circalittoral of exposed areas (more than 30 m deep). The dominant species are Phakellia ventilabrum, Axinella infundibuliformis, Axinella dissimilis and Stelligera stuposa.
- Communities of brachiopods and ascidiacea in sheltered rocky bottoms.

Circalittoral soft bottom

The main macrobenthic communities in the Cantabrian platform are:

- Dendrodoa grosularia Smititina trispinosa described by Cabioch (1961) on coastal gravel sediments (25-50 m) and characterized by the presence of Dendrodoa and Smittina with other species such as Dyastilis laevis.
- Amphiura community on sandy sediments (70-150 m), characterized by the presence of Thyasira flexuosa, Prionospio fallax, Lumbrinereis gracilis, Ampharete finmarchica, Chaetozone setosa, Terebellides ströemi, etc.., as representative species (Martínez and Adarraga, 2001).
- Auchenoplax crinite Paradiopatra calliopae Ditrupa arietina community established on sandy bottoms (150-250 m) and dominated by species such as Onchnesoma steentrupii, Galathowenia oculata and T. ströemi (Martínez and Adarraga, 2001).

Circalittoral epibenthos

Serrano et al. (2006) identified three different groups of circalittoral epibenthos:

- Assemblage of the inner shelf (30-100 m), characterized by the presence of fine sand and hermit crabs (Diogenes pugilator).

- Assemblage of the inner and middle shelf (100-200 m) with high organic sludge, characterized by fish species (Arnoglossus laterna, Callyonimus maculates, Pomatochistus sp.) and the hermit crab Anapagurus laevis.
- Assemblage of deep shelf (200-400 m), with fine and medium grain size sediments and moderate levels of organic matter, dominated by the echinoderm Ophiura affinis, the fish Lepidorhombus boscii and crustaceans of the family Crangonidae.

Protected areas

There are not protected sites designated under the Directive 92/43/CEE or other national o regional legislation in the study area. However, it should be taken into account the existence in the land and littoral zone to the west of Virgen del mar of the Special Area for Conservation (SAC) “Dunas de Liencres y estuario del Pas”.

Main pressures in the area

Santander Bay has an integral sanitation system, which integrates the sewage collection, the biological treatment at the Waste Water Treatment Plant (WWTP) and the discharge of treated effluents through a 2430 m submarine outfall, located at 42 m depth, in front of Virgen del Mar. The outfall discharges 4.5 m3 s-1 of secondary treated sewage.

Water quality

According to Echavarri-Erasun et al. (2010), no signs of eutrophication or potential for eutrophication have been observed in the proximity of the outfall discharge. Due to vertical mixing of the plume and horizontal dispersion no significant increases in nutrients and/or phytoplanktonic biomass have been observed.

2.3.6 Social perception and constraints

The Cantabria society is nowadays concerned about different emerging new technologies. Between 2008 and 2011 the government of Cantabria promoted the onshore wind development of the region. Several social initiatives led by political parties as well as other civil associations, showed up a negative perception of the initiative deeply observed on the Cantabrian society. On figure 2.3.22 an example of one of the typical pictures showed and shared on different social networks can be seen.
By 2012, the government of Cantabria, due to negative social perception decided to reduce the onshore wind development. With the aim of reduce environmental impacts to a minimum and fulfill social requirements.

On 2012 a new emerging technology, the shale gas, raised as a very promising source of incomes. However, the social perception of this new technology is highly negative. Social initiatives and political initiatives led by different organization are highlighting the negative impacts of these technologies and a significative social barrier to this technology has been set.

These two examples show how social perception in Cantabria can setup barriers that can stop different kind of initiatives.

Figure 2.322. Typical image showed by political parties as well as other civil associations, and shared on different social networks addressing the negative social perception of onshore wind developments (www.federacionacanto.org)

Mermaid project stakeholders views

On November 2012, a group of stakeholders were interviewed in order to understand their view and perception about Multiuse offshore platforms (MUP) in Cantabria.

It was found important that a MUP should not cause negative impacts on the local fishing community, but instead that a MUP could be a way of provide revenues to both the local fishing community as well as the local community in general. However, it was envisaged that it would be difficult to attract sufficient funds. Negative impacts on the ecosystem were not of large concern, perhaps since aquaculture was seen as difficult to implement.

The safety and robustness of a challenging technical construction combining wind and wave/tidal energy production is at the heart of the Atlantic Sea site. Offshore aquaculture is not seen as realistic; however a temporal island for sports events was suggested, but regardless, a good signalling system for sea vessels is crucial. The MUP must be located sufficiently far away from the coast. Funding may be difficult and clear profit must be shown to the local community and fishers. The interviewed stakeholders are willing to participate in the participatory design process, but struggle to see how they can participate in a MUP.

Recommendations for developing a design

- Try to find multi-use combinations that can stand harsh conditions.
- A safe and robust construction is required.
- No negative impacts on local fishing community.
- Focus on potential benefits so that all stakeholders can see possibilities.

2.4 The deep sheltered site, Mediterranean Sea

2.4.1 Short site description

The suggested sheltered deep water site for a multi-use platform is the Acqua Alta platform (Figure 2.4.1), a research platform held by CNR (Centro Nazionale Delle Ricerche = National Research Centre).
The platform is located in the Northern Adriatic Sea, East of Italy, 16 km off the coastline of Venice, on 16 m of depth.
The bottom is a mixture of sand and mud, deepening gently towards the southeast with a 1/1000 slope. Coordinates: latitude: 45 deg 18 min 51 sec North; longitude: 12 deg 30 min 30 sec East.
The bathymetry of the area is shown in Fig. 2.4.2.

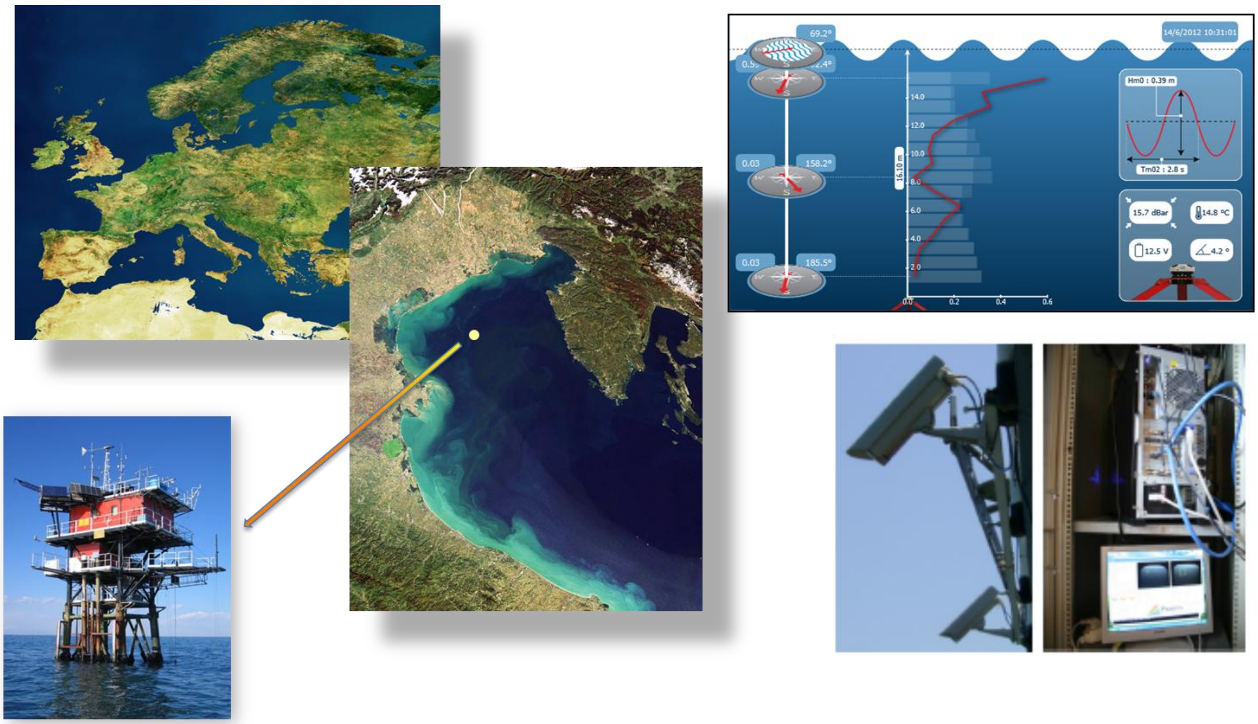


Figure 2.4.1 – Position of the site, pictures of Acqua alta platform and related instrumentation.

The Acqua Alta platform basic structure is a four leg, framed template extending 4 m above the sea surface. The template is firmly fixed on the bottom, the poles penetrating 22 m inside the sediments. The housing structure (three floors plus the top terrace) is firmly joined to the upper end of the template. The submerged part is protected by zinc anodes. The splash zone (+3, -2 m) is covered with a fully protective layer of epoxy resin.
The tower is not continuously manned. People move on board either for specific needs or for maintenance (if so, on a fortnight basis). The connection with the institute is by motor-boat with cabin and by pilot boat, both capable to stand stormy conditions. The travel time between the institute and the tower is 80 minutes.

The tower is equipped with a meteo-oceanographic station. The data are recorded on board and also telemetered to land. The station includes measurements of: atmosphere: wind (two levels), temperature, humidity, solar radiation, rain, sea: waves (directional), tide, temperature (two levels).
A number of host instrumental sets record and transmit various data to land.
On top of the regular activities, the tower is used for devoted time-limited campaigns. These have included: vertical profile of water characteristics, water quality, kinematics of water particles under stormy conditions, Reynolds stresses within the water, tidal high frequency spectrum, currents, waves breaking, suspension of sediments by waves and current, atmospheric turbulence,
vertical wind profile, Reynolds stresses in the atmosphere, surface ripples and wind by scatterometer, sea truth for satellite radiometers, sea truth for the calibration of the ERS-1 altimeter.

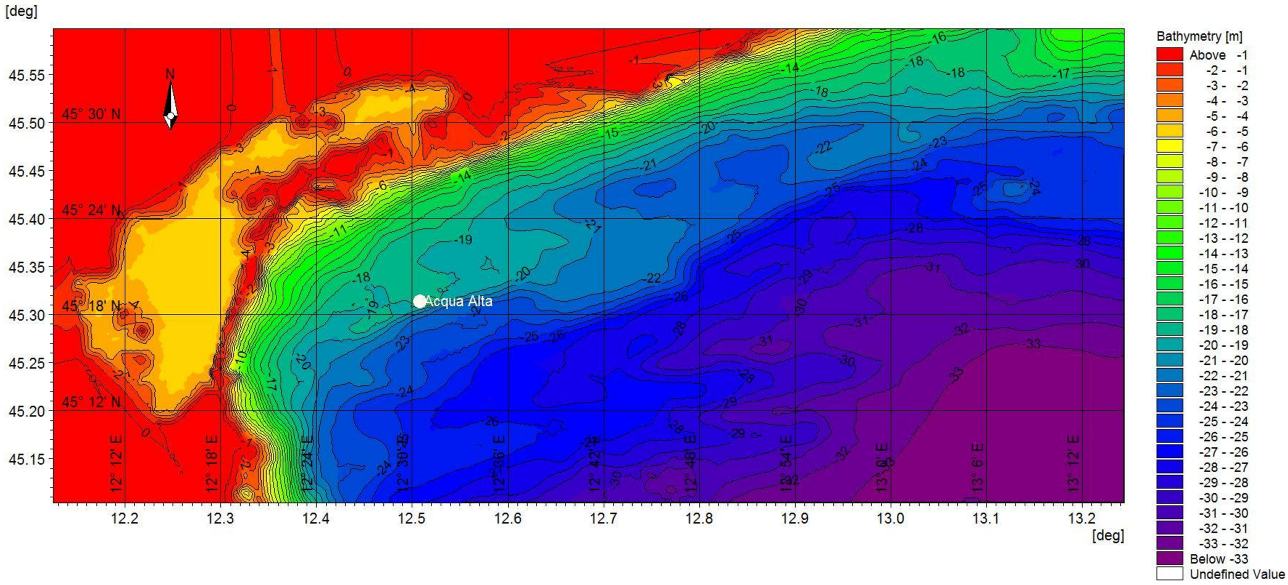


Figure 2.4.2 - Bathymetry of the area based on EMODnet data.

The area is of special cultural, technical and scientific interest. The city of Venice suffers of the Acqua Alta phenomenon, i.e. very large tides, that are threatening buildings and monuments of the area. For the defence of Venice a protection system, including mobile flood gates at the lagoon inlets is being constructed. The monitoring activities carried out at the Acqua Alta platform, since its installation in March 1970, have provided with data that has guided the design of the protection system.

In this area, the interest in wave energy production has recently increased, leading to two pilot installations of point absorbers in Venice lagoon co-funded by the Venice municipality: the GIANT in Giudecca canal (patent 2007, estimated power production: 3-5 kW/module, www.giantgiem.it) and the WEMpower in Certosa island (patent 2011, estimated power production: 35 MW/module, www.wempower.it). The installation of these devices at larger scale at the Acqua Alta platform is also planned.

Most significant environmental characteristics of the area include

- microtidal environment (< 1m tide)
- semi-enclosed basin with an average slope of 0.35 m/km and an average depth of 40 m

- high seasonal variability, sharp stratification and very high productivity rates
- peculiar biogeography and hydrology
- high population density and tourism
- eutrophication, pollution, development of coastal and marine infrastructures, Fig. 2.4.3.
- 100 offshore gas platforms in sedimentary environments (~10-120m).

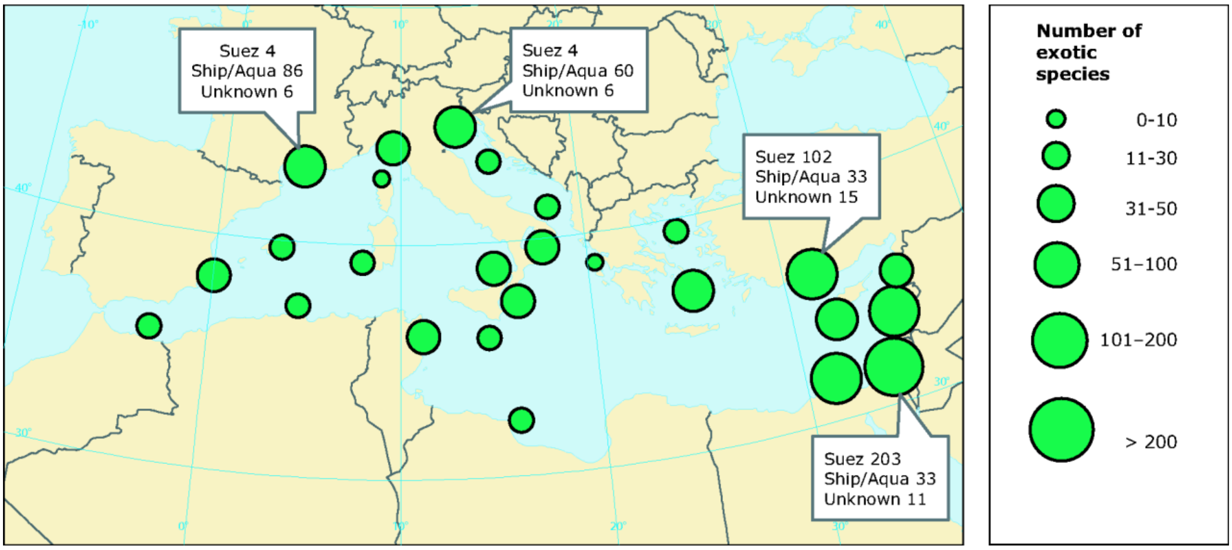


Figure 2.4.3 - Spread of exotic species in the Mediterranean.

The site is located in Regione Veneto, which is an above average size and below average populated region in Italy, although quite developed, in both economic (e.g., 26,455 euro GDP per capita) and social terms (e.g., 6% unemployment rate; 36% graduate and 10% post-graduate education). Tables 2.4.1-2.4.5 summarise data related to population, education and employment and GDP.

Table 2.4.1 Population – data refer to Regione Veneto, 2011

Area of the considered region (Sq Km)	18,378
Number of households in the region	2’048’902
Number of resident people in the region	4’937’854
Number of MALE resident people in the region	2’523’964
Number of FEMALE resident people in the region	2’413’890

Table 2.4.2 - Education – data refer to Regione Veneto, 2011

Elementary	192,576
Secondary	943,130
Baccalaureate	1,506,045
Graduate	1,792,441
Postgraduate	503,661

Table 2.4.3 - Employment and gender – data refer to Regione Veneto, 2011

Number of people in work	2,240,713
Number of people not in work	2,635,788
Unemployment rate	5.8
Male employed	1,255,353
Female employed	856,394
Male unemployed	59,163
Female unemployed	69,449

Table 2.4.4. Employment and economic activities (Thousand people) – data refer to Regione Veneto, 2011

Agriculture, Forestry and Fishing	70.7
Mining	1.4
Manufacturing	620.6
Electricity, Gas and Water Supply	7.1
Construction	184.7
Wholesale & Retail Trade	337.7
Accommodation, Cafes and Restaurants	132.9
Transport and Storage	85.4
Communication Services	47.2
Finance and Insurance	51
Property and Business Services	12
Government Administration and Defence	76.3
Education	109.9
Health and Community Services	143.6
Cultural and Recreational Services	187.7
Personal and Other Services	110.7
ALL INDUSTRIES	2178.9
Not stated or inadequately described	126.7
TOTAL	2305.6

2.4.2 **Current policy, management and planning strategies**

Within the European framework (in particular, about social and environmental issues) and the National framework (in particular, about incentives and subsidies), the Legislative Decree No. 112 of 1998 on Regional responsibility for maritime State property (Conferimento di funzioni e compiti amministrativi dello Stato alle regioni ed agli enti locali) transfers to peripheral regional agencies all functions related to maritime State property (i.e. within 12 Maritime Miles).

The Italian off-shore case study is nearby the CNR platform in the Adriatic Sea in front of Venice, within 12 Maritime Miles: we will refer to legislation of the Veneto Region, where the Regional Law No.11 of 2001 implements the Legislative Decree No.112 del 1998, and the Deliberation of the

Regional Government (Giunta Regionale del Veneto) No. 454 of 2002 on Responsibilities assigned to central and peripheral regional agencies about the maritime State property (Definizioni dei compiti assegnati alle strutture regionali centrali e periferiche nel settore del demanio marittimo) specifies to refer to peripheral offices of *Genio Civile* for concession demands for using the maritime State property.

Table 2.4.1. GDP and economic activities (Million euros) – data refer to Regione Veneto, 2011

Agriculture, Forestry and Fishing	2280.1
Mining	144.1
Manufacturing	31395.2
Electricity, Gas and Water Supply	1874
Construction	8573.8
Wholesale & Retail Trade	14697.3
Accommodation, Cafes and Restaurants	6542.1
Transport and Storage	6235.8
Communication Services	4270.4
Finance and Insurance	6147.6
Property and Business Services	17467.3
Government Administration and Defence	5883.6
Education	4622.8
Health and Community Services	6231.7
Cultural and Recreational Services	3720.1
Personal and Other Services	1142.4
ALL INDUSTRIES	121228.3
Not stated or inadequately described	9406
TOTAL	130634.3

Concessions for aquaculture

As for types, Legislative Decree No.154 of 2004, Art. 12 (7) on Modernization of the fisheries and aquaculture sectors (Modernizzazione del settore pesca e acquacoltura – Misure di conservazione e gestione delle risorse ittiche) states that "As for marine aquaculture carried out in coastal areas with essential ecological relevance for the conservation of biodiversity and of biological resources, with impacts on the maritime fishery such as ponds, lagoons, marshes (Comacchio, Delta del Po, Venice lagoon, Marano lagoon and Grado lagoon), peculiar dispositions are set up to control for environmental impact and to avoid water pollution".

Next, Legislative Decree No.11954 of 2010, Art. 4 (1) on Production of marine animals and algae by biological aquaculture (Produzione di animali e di alghe marine dell'acquacoltura biologica) states that "… in order to reduce impacts on the sea bed and on rounding sea water, current must be greater than 0.02 m/s on average per year and sea depth must be greater than 20 m … These conditions do not apply to shell-culture".

Our case study is characterized by a sea depth of 16 m and an average current of 0.3 m/s. Therefore, our multi-purpose plant should not be developed too close to the Acqua Alta CNR platform, in order to reach a 20 m sea depth.

However, Legislative Decree No.154 of 2004, Art. 10 (1) on Modernization of the fisheries and aquaculture sectors (Modernizzazione del settore pesca e acquacoltura – Commissioni consultive locali per la pesca e l'acquacoltura) states that "Regions set up consulting local commissions …".
Next, Legislative Decree No.11954 of 2010, Art. 2 (1) on Production of marine animals and algae by biological aquaculture (Produzione di animali e di alghe marine dell'acquacoltura biologica) states that "Regions are in charge of authorization for aquaculture activities …"
Therefore, as for types of aquaculture, our multi-purpose plant could develop organic and conventional aquaculture activities, either algae or sea bass, with similar ex-ante and ex-post controls on environmental issues by the peripheral offices of Genio Civile, together with the Consulting Regional Commissions.
Indeed, all types of aquaculture will refer to the same EU legislation (710/2009; 1005/2008; 889/2008; 834/2007), to the same control agencies (i.e. regional authorities for sustainable management) and to the same EU principles implemented by national legislation (Legislative Decree No.11954 of 2010, Art. 1 (1) on Production of marine animals and algae by biological aquaculture; Legislative Decree No. 226 of 2001 on Guidelines and organization of fisheries and aquaculture sectors):

a. Environmental monitoring, with focus on water quality and nutrient discharges, …
b. Protocols for production phases
c. Production capacity
d. Assessment of wild biomass
e. Data on yearly nutrient discharges per production plant
f. Regeneration of marine algae
g. Multi-culture systems
h. Maintenance and repair of technical equipment
i. Waste reduction
j. Document keeping

As regards sizes, the Deliberation of the Regional Government (Giunta Regionale del Veneto) No.412 of 2009 eliminates the maximum increase (10% of the extension of 2600 ha) specified by the Deliberation of the Regional Government No. 1754 of 2008, which increased the maximum increase (3% of the extension of 2600 ha) specified by the Deliberation of the Regional Government No.2948 of 2007 on Integrative dispositions about maritime state property concession release for fish and aquaculture activities (Disposizioni concernenti il rilascio delle concessioni demaniali marittime per attività di pesca e acquacoltura), by introducing ex-ante assessments at macro-system level such as:

- environmental sustainability of impacts on marine ecosystems, by taking into account the fishery relying on coastal resources;
- optimal location of plants, by considering the alternative uses of the maritime State property (e.g. production activities, infrastructure, services, environmental protection, …) within a planning approach involving the whole coastal areas;
- impacts of increased production on prices, employment and profitability of aquaculture activities.

Therefore, as for sizes of aquaculture, our multi-purpose plant could now face quite a weak competition by other firms.
Note that the Legislative Decree No. 4 of 2012, Art.7 (1) on Dispositions for reorganization of normative framework on fisheries and aquaculture (Misure per il riassetto della normative in materia di pesca e acquacoltura) introduces fines and temporary suspension up to permanent

withdraw of concessions in order to preserve marine biological resources as well as to prevent, discourage and eliminate illegal, undeclared or unregulated fishery.

Funds for fishery and aquaculture

As for incentives, for insurance, within EU Regulation No.1263 of 1999 on the Financial instrument for fisheries guidance, the Legislative Decree No.100 of 2005 on Further provisions for the modernization of the fisheries and aquaculture sectors (Ulteriori disposizioni per la modernizzazione dei settori della pesca e dell'acquacoltura), in order to favor insurance contracts covering structural risks linked to natural events, meteorological conditions and prices fluctuations, states that "up to 80% of insurance premium can be refunded by the State …", by specifying conditions to be met.

As for subsidies, for investments, within EU Regulation No.2792 of 1999 on Community structural assistance in the fisheries sector, the Deliberation of the Regional Government (Giunta Regionale del Veneto) No. 3316 of 2007 on Subsidies for fish and aquaculture activities (Interventi nel settore della pesca e dell'acquacoltura, complemento di programmazione regionale cofinanziato dallo SFOP) states that "up to 50% of expenditures can be reimbursed by the Region …", by specifying conditions to be met.

Concessions for energy

As for sizes and locations, the Circular Letter No. 40 of 2012 by the General Direction of the Ministry of Infrastructures and Transports on off-shore plants for energy production from renewable resources (Razionalizzazione e semplificazione delle procedure autorizzative fonti energetiche rinnovabili), actually focused on wind plants, states that authorisations for construction and operation is issued by the Ministry of Infrastructures and Transports, once consulted the Ministry of Economic Development and the Ministry of the Environment, … provided concessions of the maritime State property use by the peripheral offices of Genio Civile (Law No. 244 of 2007, which modifies the Legislative Decree No.387 of 2003).

Funds for energy

As for incentives, Legislative Decree No. 28 of 2011 on Incentives for energy from renewable sources, which implements the Directive No. 28 of 2009 on the Promotion of the use of energy from renewable sources, ensures 0.34 € per kWh for all plants smaller than 5 MW producing energy from marine renewable sources. Note that the unique working plant in Italy is of 50 kW.

As for subsidies, there is no national or regional legislation on that.

Current Practices

There are no current experiences in fish or energy farms in Veneto. However, a sea-bass pilot project (i.e. 18,000 fishes and 300 m2) has been developed by the Veneto Region in 2008-2010 in Porto Tolle (RO), in order to test the technical, economic and environmental sustainability of a bio-production: large potentials have been highlighted.

2.4.3 **Metocean conditions and renewable energy potential**

Data analysis: Waves

The wave measurements, collected at the Acqua Alta Tower, cover a period from 1987 up to 2008. Figure 2.4.4 shows the time series of the significant wave heights Hs that occurred in the measurement period. It is worth to mention that the maximum measured wave height is little greater than 4 m. This is consistent with the wave features of the North Adriatic Sea (i.e., enclosed basin with relatively small fetches).

In order to assess the mean annual wave regime, Figure 2.4.5 represents the frequency/direction/intensity diagram (i.e. rose diagram). Wave heights, as well as, wave directions have been divided into classes, see also Figure 2.4.6. Thus for each wave height/direction class the percentage of occurrence can be obtained and, accordingly, plotted. The rose diagram clearly shows that two main directions appear. The prevailing direction (hereinafter BORA) from which both frequent and extreme waves can come is included in the angular range between 0°N and 85°N. The secondary direction (hereinafter SCIROCCO) from which both frequent and extreme waves can come is included in the angular range between 105°N and 175°N. It is worth to highlight that the highest waves seem to come from BORA direction.

Tables 2.4.6 and 2.4.7 synthesise the annual wave climate based on classes of wave heights and wave directions and period respectively.

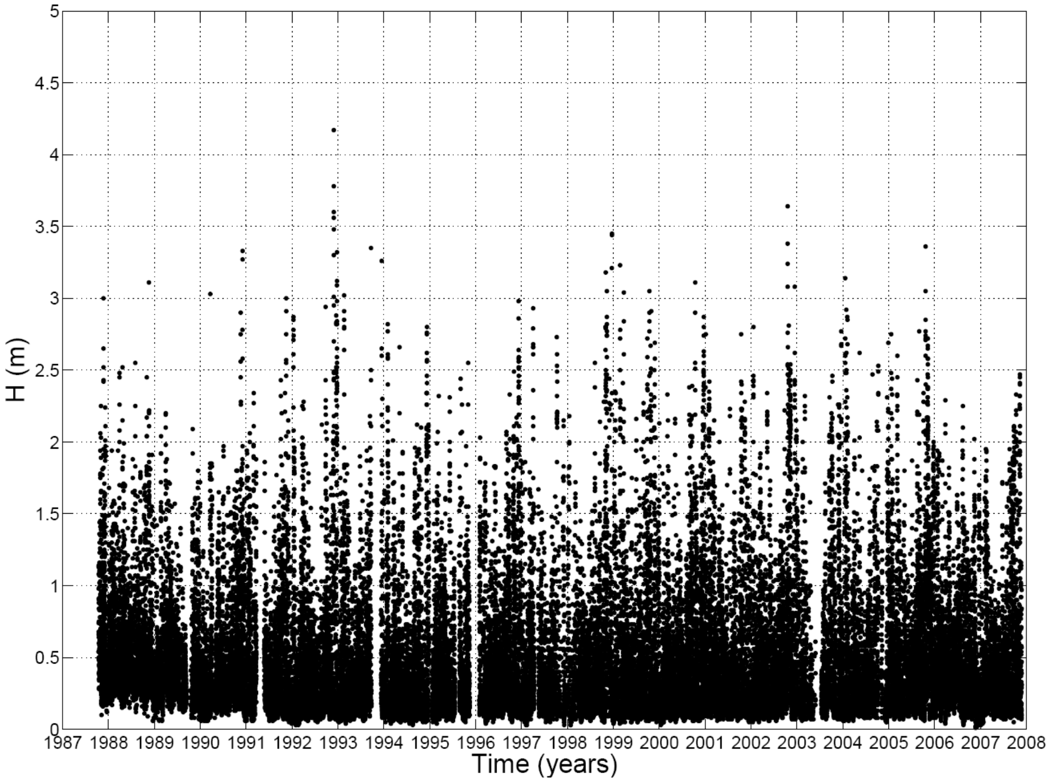


Figure 2.4.4 - Time series of significant wave height (measurements since 1987 up to 2008).

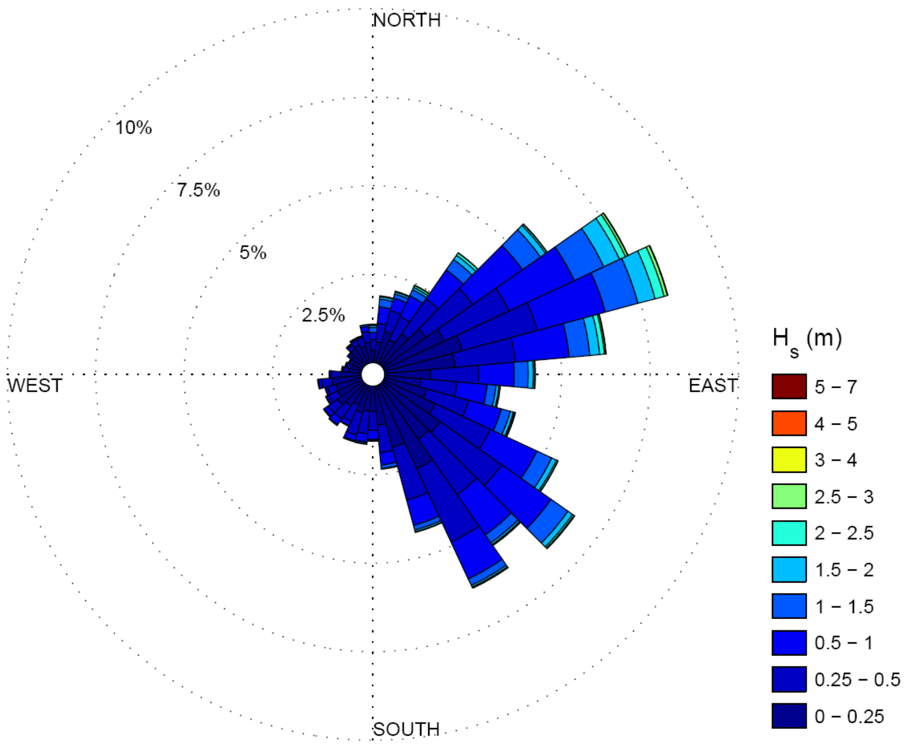


Figure 2.4.5 - Mean annual wave regime (rose diagram), based on measurements in Fig. 2.4.4.

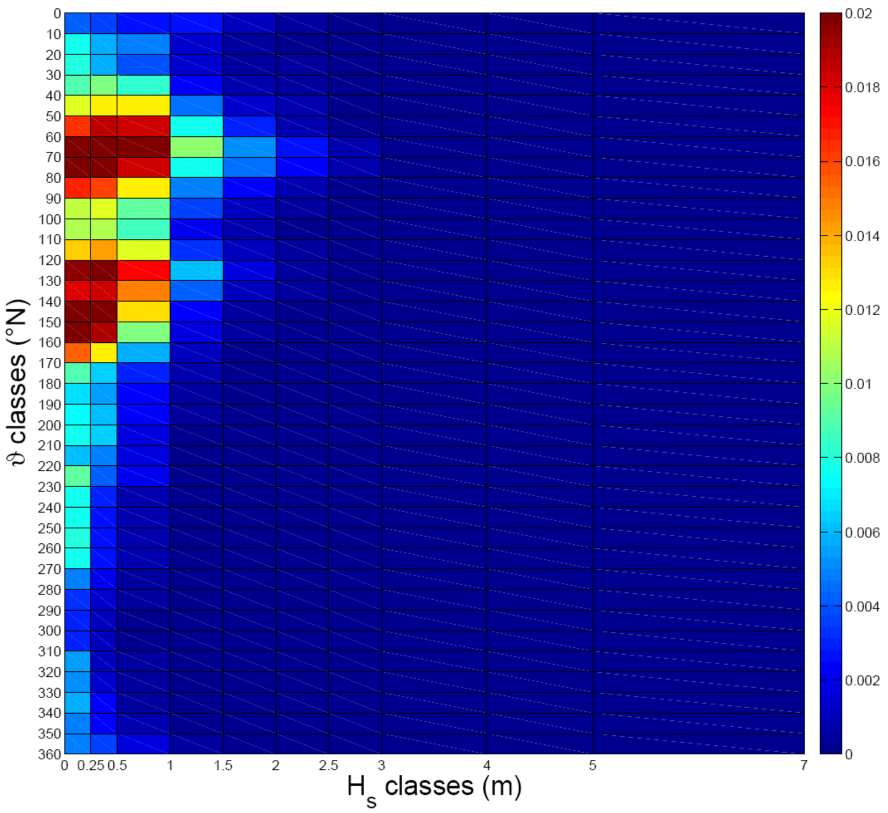


Figure 2.4.6 Annual wave regime highlighting the prevailing wave directions.

DIR\H	0 - 0.25 m	0.25 - 0.5 m	0.5 - 1 m	1 - 1.5 m	1.5 - 2 m	2 - 2.5 m	2.5 - 3 m	3 - 4 m	4 - 5 m	5 - 7 m	
0° - 10°	0.435	0.359	0.275	0.269	0.100	0.041	0.016	0.00	0.00	0.00	**1.49**
10° - 20°	0.777	0.588	0.482	0.126	0.049	0.002	0.002	0.00	0.00	0.00	**2.03**
20° - 30°	0.802	0.586	0.396	0.145	0.059	0.041	0.008	0.00	0.00	0.00	**2.04**
30° - 40°	0.888	0.975	0.828	0.231	0.071	0.051	0.004	0.00	0.00	0.00	**3.05**
40° - 50°	1.185	1.275	1.255	0.445	0.147	0.086	0.004	0.00	0.00	0.00	**4.40**
50° - 60°	1.630	1.851	1.842	0.771	0.298	0.071	0.025	0.00	0.00	0.00	**6.49**
60° - 70°	2.128	2.077	2.126	1.006	0.524	0.253	0.088	0.02	0.00	0.00	**8.22**
70° - 80°	2.275	2.061	1.834	0.775	0.449	0.224	0.080	0.02	0.00	0.00	**7.71**
80° - 90°	1.671	1.620	1.269	0.479	0.228	0.088	0.024	0.01	0.00	0.00	**5.38**
90° - 100°	1.094	1.179	0.912	0.367	0.114	0.033	0.012	0.01	0.00	0.00	**3.72**
100° - 110°	1.088	1.083	0.863	0.218	0.071	0.024	0.002	0.01	0.00	0.00	**3.36**
110° - 120°	1.343	1.410	1.167	0.318	0.112	0.039	0.014	0.01	0.00	0.00	**4.41**
120° - 130°	1.959	2.044	1.734	0.612	0.184	0.053	0.006	0.00	0.00	0.00	**6.59**
130° - 140°	1.812	1.844	1.485	0.408	0.100	0.043	0.018	0.00	0.00	0.00	**5.71**
140° - 150°	2.340	2.240	1.310	0.237	0.061	0.024	0.000	0.00	0.00	0.00	**6.21**
150° - 160°	2.202	1.904	0.981	0.165	0.059	0.029	0.004	0.00	0.00	0.00	**5.34**
160° - 170°	1.551	1.261	0.563	0.122	0.029	0.004	0.000	0.00	0.00	0.00	**3.53**
170° - 180°	0.900	0.653	0.292	0.075	0.012	0.004	0.002	0.00	0.00	0.00	**1.94**
180° - 190°	0.679	0.561	0.220	0.035	0.014	0.002	0.000	0.00	0.00	0.00	**1.51**
190° - 200°	0.735	0.614	0.222	0.035	0.006	0.002	0.000	0.00	0.00	0.00	**1.61**
200° - 210°	0.751	0.641	0.157	0.022	0.006	0.002	0.000	0.00	0.00	0.00	**1.58**
210° - 220°	0.608	0.498	0.157	0.029	0.002	0.000	0.000	0.00	0.00	0.00	**1.29**
220° - 230°	0.926	0.420	0.194	0.022	0.000	0.000	0.000	0.00	0.00	0.00	**1.56**
230° - 240°	0.751	0.292	0.088	0.018	0.004	0.000	0.000	0.00	0.00	0.00	**1.15**
240° - 250°	0.771	0.253	0.067	0.012	0.000	0.002	0.000	0.00	0.00	0.00	**1.10**
250° - 260°	0.810	0.255	0.075	0.006	0.002	0.000	0.000	0.00	0.00	0.00	**1.15**
260° - 270°	0.769	0.269	0.082	0.022	0.000	0.000	0.000	0.00	0.00	0.00	**1.14**
270° - 280°	0.477	0.204	0.039	0.012	0.002	0.002	0.000	0.00	0.00	0.00	**0.74**
280° - 290°	0.343	0.149	0.035	0.010	0.000	0.000	0.000	0.00	0.00	0.00	**0.54**
290° - 300°	0.300	0.104	0.027	0.008	0.000	0.000	0.000	0.00	0.00	0.00	**0.44**
300° - 310°	0.306	0.096	0.029	0.006	0.002	0.002	0.000	0.00	0.00	0.00	**0.44**
310° - 320°	0.533	0.114	0.035	0.004	0.002	0.000	0.000	0.00	0.00	0.00	**0.69**
320° - 330°	0.522	0.133	0.041	0.006	0.002	0.000	0.000	0.00	0.00	0.00	**0.70**
330° - 340°	0.573	0.224	0.037	0.008	0.002	0.000	0.000	0.00	0.00	0.00	**0.84**
340° - 350°	0.477	0.233	0.067	0.025	0.000	0.000	0.000	0.00	0.00	0.00	**0.80**
350° - 360°	0.486	0.353	0.186	0.047	0.006	0.002	0.000	0.00	0.00	0.00	**1.08**
	36.90	**30.42**	**21.37**	**7.09**	**2.71**	**1.12**	**0.31**	**0.07**	**0.00**	**0.00**	**100.00**

Table 2.4.6. Mean annual wave regime considering classes of wave heights and wave directions.

As far as the wave energy conversion is concerned, it is essential to assess the duration, in terms of day/year, of a certain wave height that exceeds a given threshold. This can be done by means of the duration curve (see Fig.2.4.7). As previously mentioned the North Adriatic Sea is an enclosed basin with small fetches. It implies that reasonable technical/economic conditions that grant wave energy conversion to be feasible are quite rare during a year.
The duration curve itself does not provide all the engineering quantities that allow to assess the feasibility of the wave energy conversion. Also the mean condition in terms of the wave periods, of course related to the wave heights, have to be considered. In order to obtain these helpful engineering quantities the Table 2.4.7 and Figure 2.4.8 are presented.

T\H	0 - 0.25 m	0.25 - 0.5 m	0.5 - 1 m	1 - 1.5 m	1.5 - 2 m	2 - 2.5 m	2.5 - 3 m	3 - 4 m	4 - 5 m	5 - 7 m	
0 - 1 s	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**0.00**
1 - 2 s	0.990	0.449	0.004	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**1.44**
2 - 3 s	10.243	5.417	0.326	0.010	0.000	0.002	0.000	0.00	0.00	0.00	**16.00**
3 - 4 s	15.566	14.178	5.944	0.200	0.008	0.008	0.000	0.00	0.00	0.00	**35.91**
4 - 5 s	5.954	6.666	9.455	2.683	0.273	0.055	0.014	0.00	0.00	0.00	**25.10**
5 - 6 s	2.404	2.248	3.454	2.553	1.375	0.473	0.029	0.00	0.00	0.00	**12.54**
6 - 7 s	1.045	0.930	1.543	1.088	0.626	0.363	0.204	0.02	0.00	0.00	**5.82**
7 - 8 s	0.398	0.355	0.471	0.426	0.284	0.163	0.043	0.02	0.00	0.00	**2.16**
8 - 9 s	0.149	0.127	0.116	0.084	0.086	0.037	0.010	0.01	0.00	0.00	**0.63**
9 - 10 s	0.067	0.033	0.037	0.016	0.027	0.014	0.006	0.01	0.00	0.00	**0.21**
10 - 12 s	0.06	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	**0.14**
12 - 14 s	0.02	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	**0.05**
14 - 16 s	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
	36.90	**30.42**	**21.37**	**7.09**	**2.71**	**1.12**	**0.31**	**0.07**	**0.00**	**0.00**	**100.00**

Table 2.4.7 - Wave period-wave height (global).

Figure 2.4.9 represents a scatter plot on which each wave measurement can be visualized (black dots). Blue and red lines identify the angular sector of the two direction BORA and SCIROCCO respectively. Blue and red dots represent the wave event that own to each direction.
Given this, it would be more meaningful to perform a wave/period analysis on each direction, rather than in a global (i.e. omnidirectional) manner. The results of this analysis are shown in Tables 2.4.8-2.4.9 and Figures 2.4.10-2.4.11 for the BORA and SCIROCCO directions respectively.

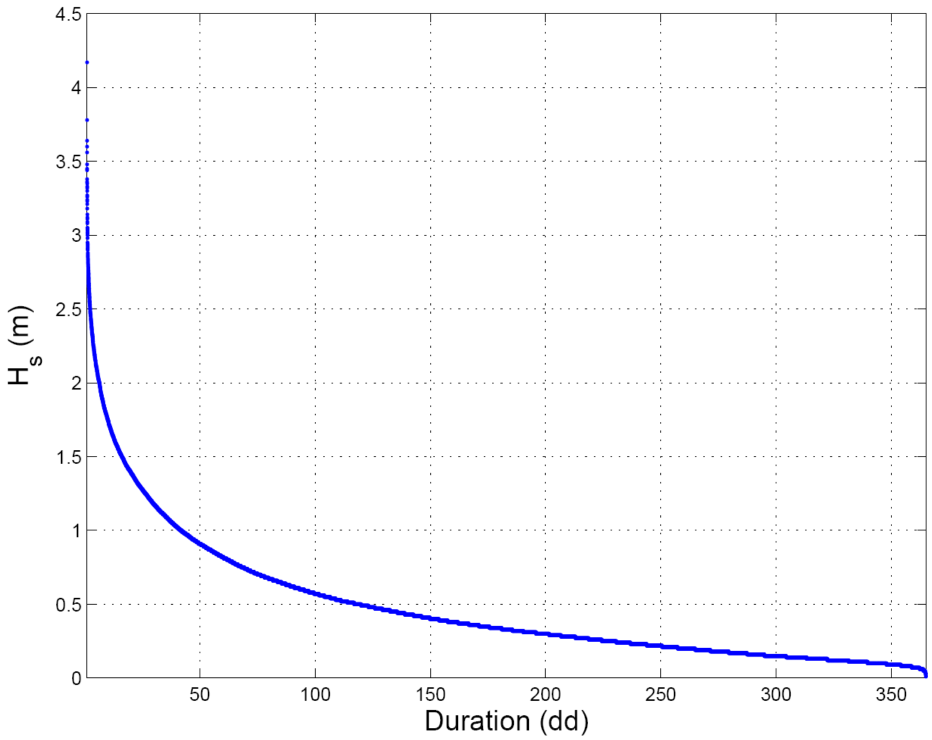


Figure 2.4.7 - Wave duration curve.

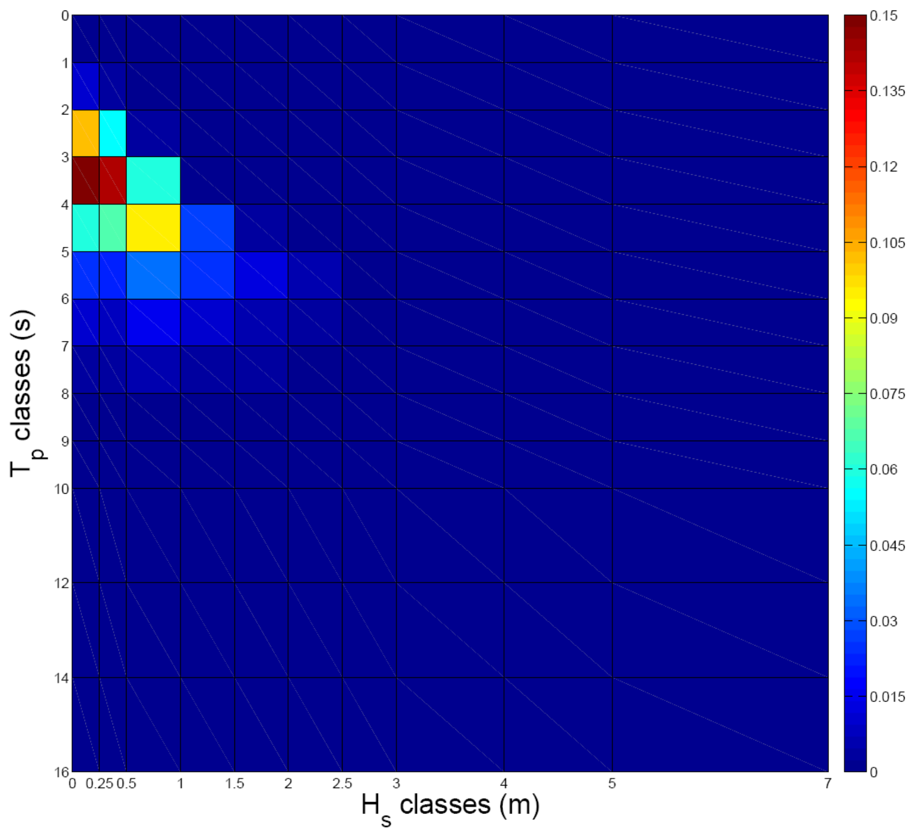


Figure 2.4.8. Wave period-wave height (global)

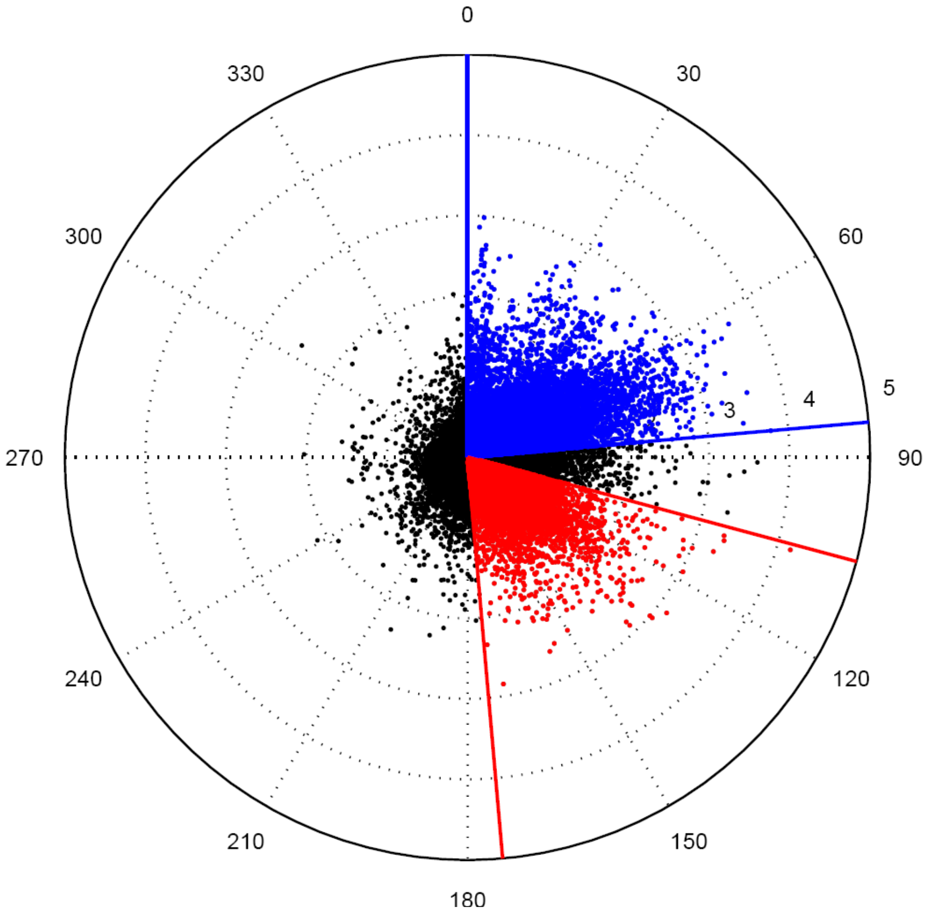


Figure 2.4.9. Scatter plot.

T\H	0 - 0.25 m	0.25 - 0.5 m	0.5 - 1 m	1 - 1.5 m	1.5 - 2 m	2 - 2.5 m	2.5 - 3 m	3 - 4 m	4 - 5 m	5 - 7 m	
0 - 1 s	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**0.00**
1 - 2 s	0.241	0.188	0.004	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**0.43**
2 - 3 s	2.912	1.877	0.153	0.004	0.000	0.002	0.000	0.00	0.00	0.00	**4.95**
3 - 4 s	4.879	5.307	3.158	0.112	0.004	0.004	0.000	0.00	0.00	0.00	**13.46**
4 - 5 s	1.920	2.261	4.695	1.849	0.200	0.031	0.006	0.00	0.00	0.00	**10.96**
5 - 6 s	0.767	0.661	1.236	1.494	1.067	0.408	0.022	0.00	0.00	0.00	**5.65**
6 - 7 s	0.343	0.294	0.479	0.467	0.390	0.275	0.180	0.02	0.00	0.00	**2.45**
7 - 8 s	0.108	0.120	0.122	0.133	0.116	0.088	0.027	0.01	0.00	0.00	**0.72**
8 - 9 s	0.033	0.051	0.025	0.016	0.033	0.016	0.006	0.00	0.00	0.00	**0.18**
9 - 10 s	0.008	0.012	0.010	0.004	0.008	0.006	0.002	0.00	0.00	0.00	**0.05**
10 - 12 s	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	**0.06**
12 - 14 s	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	**0.02**
14 - 16 s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	11.23	**10.78**	**9.89**	**4.10**	**1.84**	**0.84**	**0.25**	**0.04**	**0.00**	**0.00**	**38.96**

Table 2.4.9 - Wave period-wave height (BORA conditions only)

T\H	0 - 0.25 m	0.25 - 0.5 m	0.5 - 1 m	1 - 1.5 m	1.5 - 2 m	2 - 2.5 m	2.5 - 3 m	3 - 4 m	4 - 5 m	5 - 7 m	
0 - 1 s	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**0.00**
1 - 2 s	0.365	0.116	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**0.48**
2 - 3 s	3.322	1.783	0.082	0.006	0.000	0.000	0.000	0.00	0.00	0.00	**5.19**
3 - 4 s	5.038	5.109	1.687	0.033	0.004	0.004	0.000	0.00	0.00	0.00	**11.88**
4 - 5 s	1.938	2.820	3.163	0.449	0.041	0.018	0.008	0.00	0.00	0.00	**8.44**
5 - 6 s	0.861	1.118	1.649	0.718	0.141	0.031	0.006	0.00	0.00	0.00	**4.52**
6 - 7 s	0.400	0.445	0.837	0.486	0.194	0.065	0.016	0.00	0.00	0.00	**2.44**
7 - 8 s	0.192	0.177	0.277	0.245	0.145	0.063	0.010	0.00	0.00	0.00	**1.11**
8 - 9 s	0.082	0.055	0.076	0.059	0.031	0.018	0.002	0.01	0.00	0.00	**0.33**
9 - 10 s	0.041	0.012	0.016	0.012	0.016	0.006	0.004	0.00	0.00	0.00	**0.11**
10 - 12 s	0.03	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	**0.05**
12 - 14 s	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**
14 - 16 s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	12.28	**11.64**	**7.80**	**2.02**	**0.58**	**0.20**	**0.05**	**0.02**	**0.00**	**0.00**	**34.58**

Table 2.4.10 - Wave period-wave height (SCIROCCO conditions only)

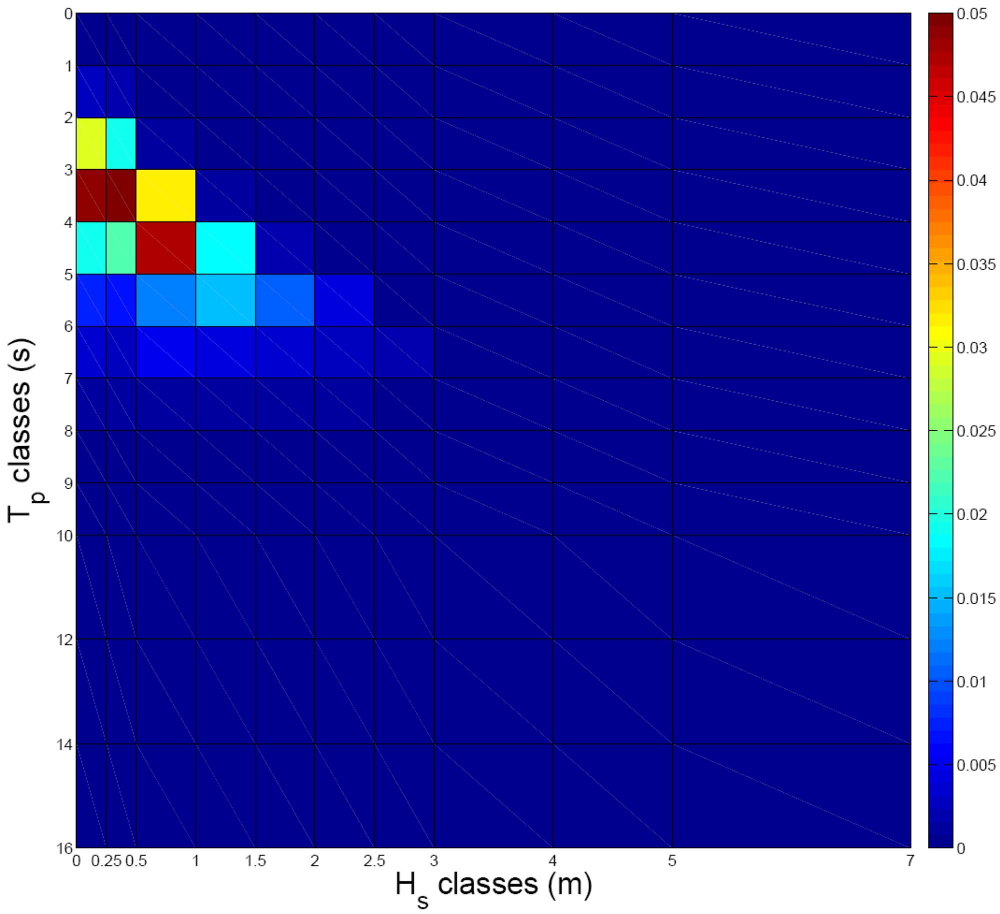


Figure 2.4.10. Wave period-wave height (BORA)

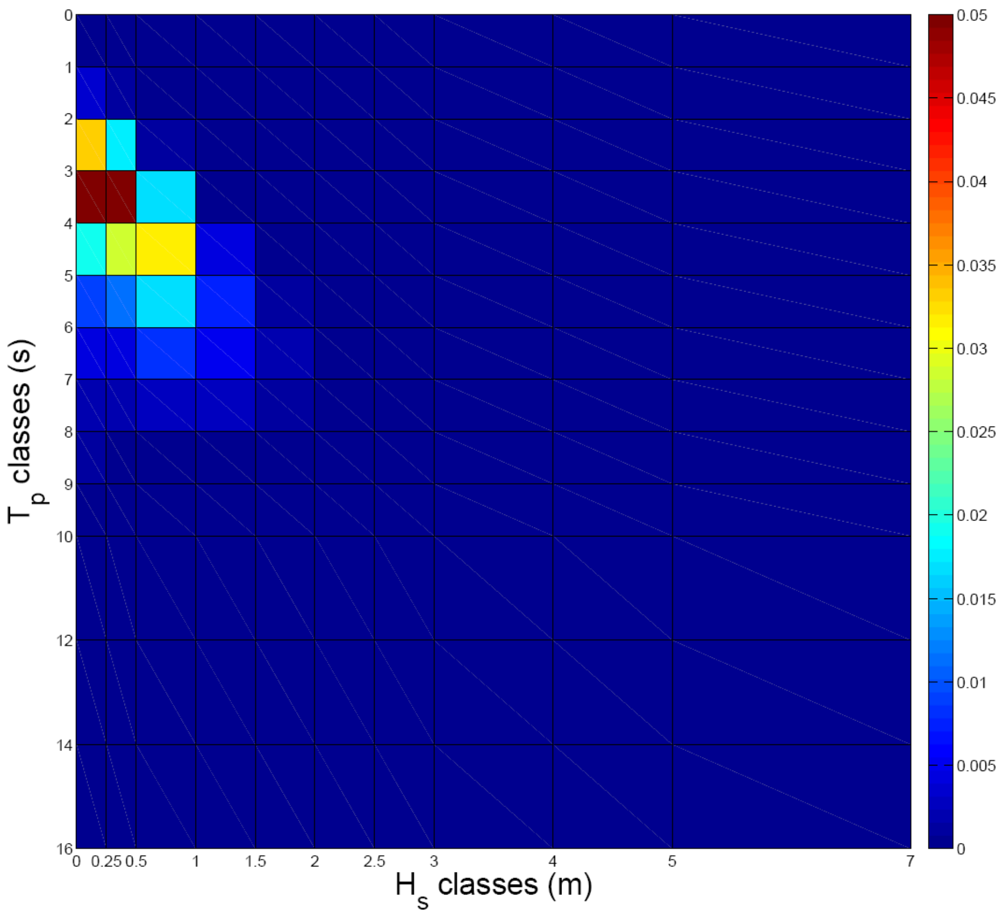


Figure 2.4.11. Wave period-wave height (SCIROCCO)

Data analysis: Energy

Once the wave data have been analysed it could be helpful to evaluate the power related to the wave condition. As far as wave energy conversion in concerned it is preferable to look also at the available suitable power. This is quite convenient since this quantity takes into account both the magnitude of the wave height and the wave period as well.

The power per unit wave front is calculated according to the following equation: $P = \frac{1}{64\pi}\rho g^2 H_s^2 T_e$.

Figure 2.4.12 shows the frequency/direction/intensity diagram in terms of the power per unit wavefront. As for the wave conditions also Table 2.4.11 and Figure 2.4.12 are provided. It is worth to mention that also for the power per unit wave front the BORA and SCIROCCO direction can be identified, see Figure 2.4.13.

Accordingly to the wave data analysis the duration curve is provided in Figure 2.4.14.

Figure 2.4.14 shows the power data analysis in terms of the mean power per unit wave front. Each black dot represents the averaged value of the power per unit wave front for each direction class. The direction classes are defined as in Table 2.4.11.

In Figure 2.4.15 also the angular sectors of BORA and SCIROCCO direction are provided (blue and red lines respectively). It is worth to highlight that in those angular sectors the averaged power per unit wave front are in the order of 2-3 kW/m. Given the wave condition of the Mediterranean site this appears consistent.

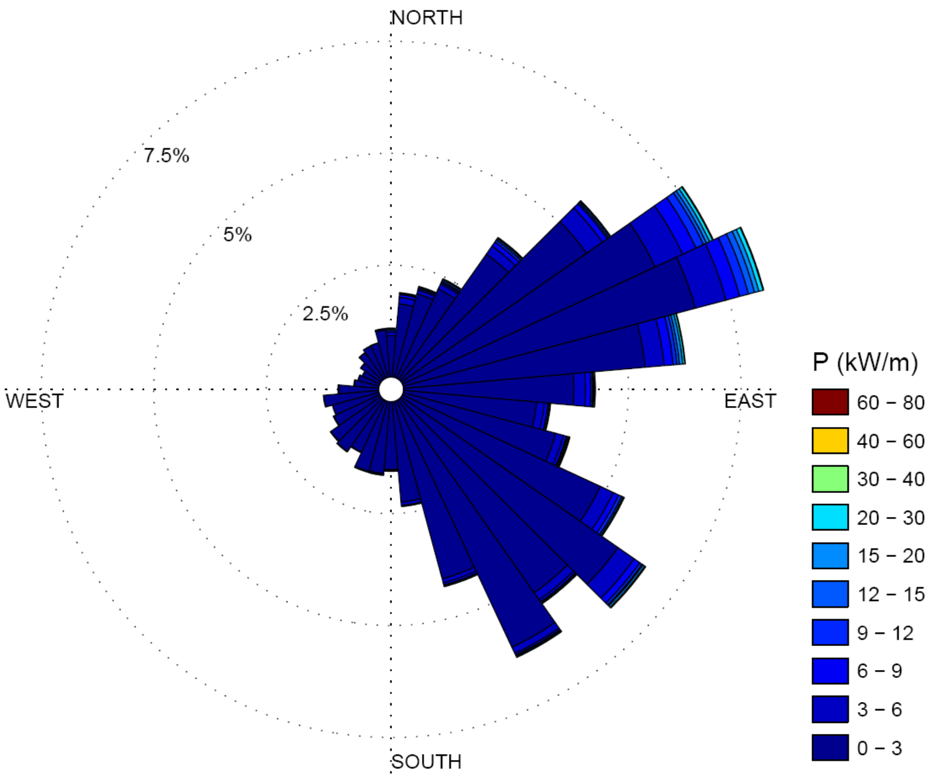


Figure 2.4.12. Power per unit wave front regime

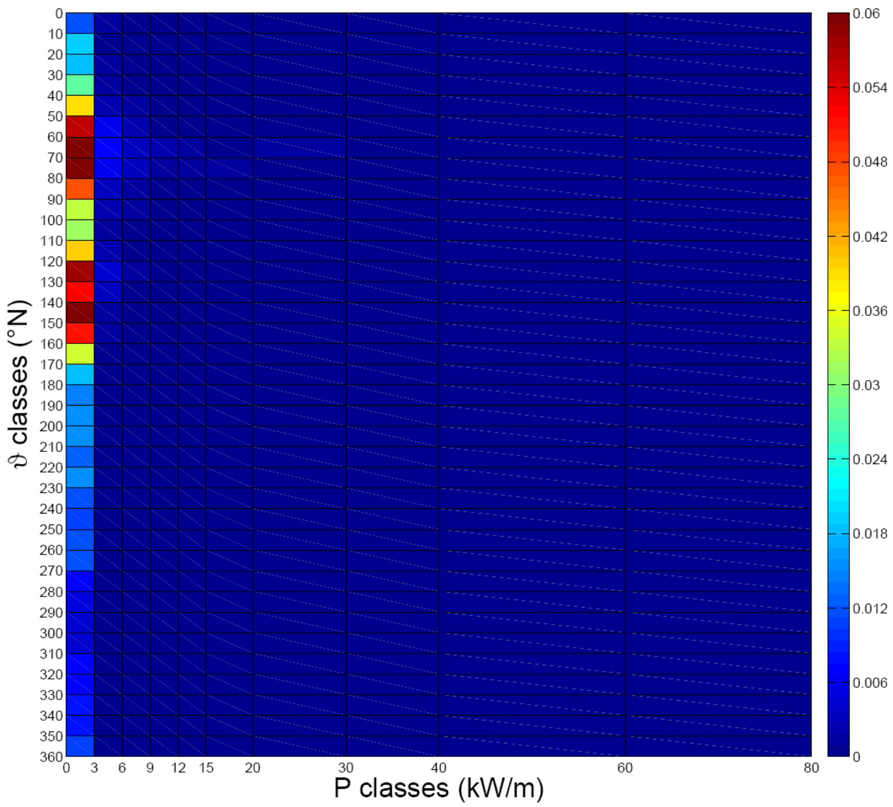


Figure 2.4.13 Power per unit wavefront regime

DIR\EN	0 - 3 kW/m	3 - 6 kW/m	6 - 9 kW/m	9 - 12 kW/m	12 - 15 kW/m	15 - 20 kW/m	20 - 30 kW/m	30 - 40 kW/m	40 - 60 kW/m	60 - 80 kW/m	
0° - 10°	1.163	0.167	0.076	0.029	0.018	0.031	0.008	0.00	0.00	0.00	**1.49**
10° - 20°	1.885	0.088	0.037	0.012	0.002	0.000	0.002	0.00	0.00	0.00	**2.03**
20° - 30°	1.830	0.098	0.037	0.022	0.027	0.018	0.006	0.00	0.00	0.00	**2.04**
30° - 40°	2.795	0.133	0.043	0.024	0.033	0.018	0.002	0.00	0.00	0.00	**3.05**
40° - 50°	3.877	0.280	0.110	0.059	0.041	0.025	0.004	0.00	0.00	0.00	**4.40**
50° - 60°	5.544	0.584	0.206	0.069	0.029	0.031	0.022	0.00	0.00	0.00	**6.49**
60° - 70°	6.611	0.710	0.347	0.218	0.129	0.092	0.096	0.01	0.01	0.00	**8.22**
70° - 80°	6.368	0.588	0.294	0.159	0.104	0.100	0.082	0.02	0.00	0.00	**7.71**
80° - 90°	4.699	0.329	0.167	0.071	0.039	0.045	0.029	0.00	0.00	0.00	**5.38**
90° - 100°	3.291	0.249	0.100	0.033	0.012	0.016	0.008	0.01	0.00	0.00	**3.72**
100° - 110°	3.095	0.149	0.061	0.020	0.010	0.010	0.004	0.00	0.00	0.00	**3.36**
110° - 120°	4.026	0.210	0.078	0.027	0.025	0.018	0.016	0.01	0.00	0.00	**4.41**
120° - 130°	5.809	0.431	0.186	0.084	0.043	0.029	0.010	0.00	0.00	0.00	**6.59**
130° - 140°	5.197	0.318	0.082	0.047	0.014	0.035	0.016	0.00	0.00	0.00	**5.71**
140° - 150°	5.962	0.159	0.047	0.016	0.010	0.014	0.004	0.00	0.00	0.00	**6.21**
150° - 160°	5.109	0.124	0.047	0.033	0.022	0.006	0.004	0.00	0.00	0.00	**5.34**
160° - 170°	3.395	0.088	0.031	0.014	0.000	0.002	0.000	0.00	0.00	0.00	**3.53**
170° - 180°	1.857	0.065	0.006	0.004	0.002	0.002	0.002	0.00	0.00	0.00	**1.94**
180° - 190°	1.469	0.020	0.010	0.010	0.002	0.000	0.000	0.00	0.00	0.00	**1.51**
190° - 200°	1.591	0.018	0.002	0.002	0.000	0.002	0.000	0.00	0.00	0.00	**1.61**
200° - 210°	1.555	0.012	0.004	0.002	0.004	0.000	0.002	0.00	0.00	0.00	**1.58**
210° - 220°	1.273	0.020	0.002	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**1.29**
220° - 230°	1.545	0.014	0.002	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**1.56**
230° - 240°	1.139	0.010	0.002	0.002	0.000	0.000	0.000	0.00	0.00	0.00	**1.15**
240° - 250°	1.096	0.006	0.000	0.000	0.002	0.000	0.000	0.00	0.00	0.00	**1.10**
250° - 260°	1.141	0.006	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**1.15**
260° - 270°	1.130	0.012	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**1.14**
270° - 280°	0.720	0.014	0.000	0.000	0.002	0.000	0.000	0.00	0.00	0.00	**0.74**
280° - 290°	0.530	0.008	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**0.54**
290° - 300°	0.435	0.002	0.002	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**0.44**
300° - 310°	0.435	0.002	0.000	0.002	0.000	0.002	0.000	0.00	0.00	0.00	**0.44**
310° - 320°	0.683	0.004	0.002	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**0.69**
320° - 330°	0.700	0.002	0.000	0.002	0.000	0.000	0.000	0.00	0.00	0.00	**0.70**
330° - 340°	0.841	0.000	0.002	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**0.84**
340° - 350°	0.792	0.010	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	**0.80**
350° - 360°	1.041	0.029	0.006	0.004	0.000	0.000	0.000	0.00	0.00	0.00	**1.08**
	90.63	**4.96**	**1.99**	**0.96**	**0.57**	**0.50**	**0.32**	**0.05**	**0.02**	**0.00**	**100.00**

Table 2.4.11. Power per unit wavefront regime

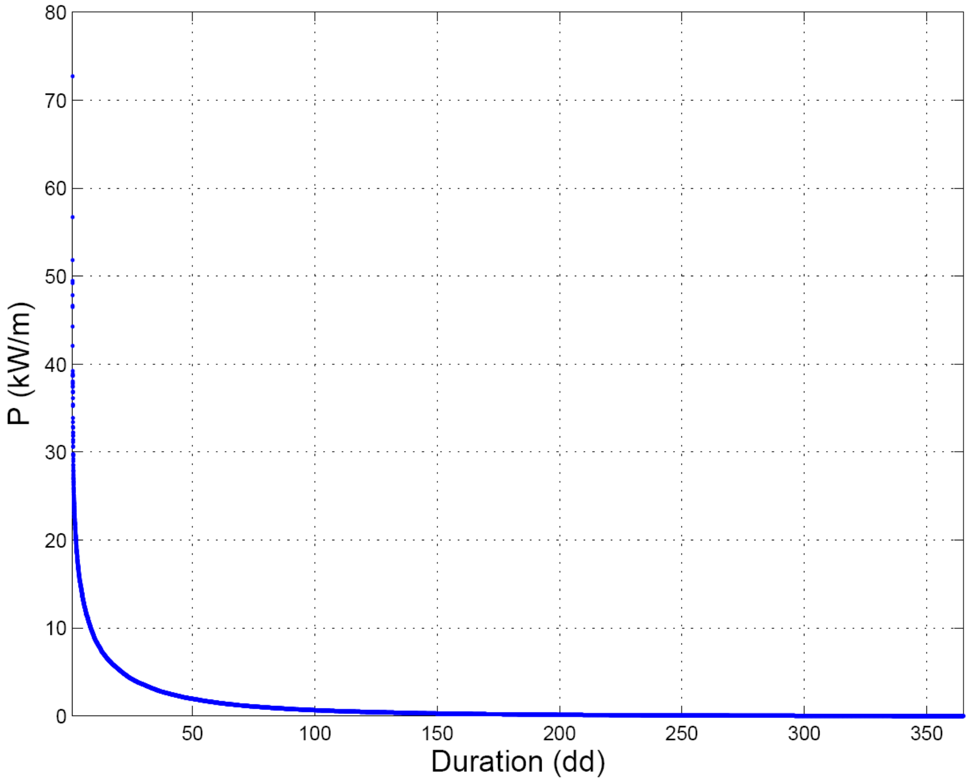


Figure 2.4.14. Duration curve of power per unit wave front

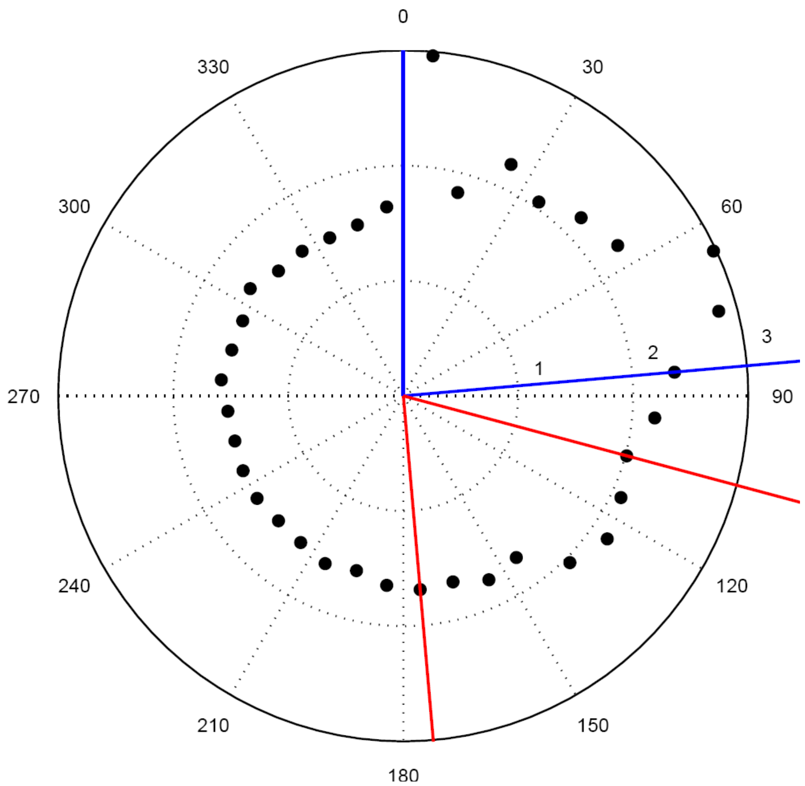


Figure 2.4.15 -. Averaged values of power per unit wave front

Extreme values analysis: Waves

Aiming at providing the wave design parameters for the wave energy converters also the analysis of the extreme values has been carried out considering:

- omnidirectional extreme value analysis;
- extreme value analysis for the angular sector BORA;
- extreme value analysis for the angular sector SCIROCCO.

The Peak Over Threshold method (hereinafter POT) has been used. As it is well known this method is based on the choice of a meaningful wave height threshold that should ensure to select an homogeneous and statistically independent set of data to be used.

The wave height threshold for the omnidirectional wave analysis was fixed to 2.5 m.

Figure 2.4.16 shows the results of the selection procedure. The red dots identify the homogeneous and statistically independent extreme events to be used. Figure 2.4.17 shows by means of a scatter plot the extreme events (red circles), while the red dashed line identify the wave height threshold.

In order to choose the probability density function (hereinafter PDF) to be used to obtain the design parameter as a function of the return period Figure 2.4.18 is presented. Three PDFs have been used, namely that of Gumbel, Frechet and GEV. It is possible to see that GEV distribution seems to better fit the empirical observations. Figure 2.4.19 and Table 2.4.12 describe the extrapolation procedure and provide the design wave height as a function of the return period.

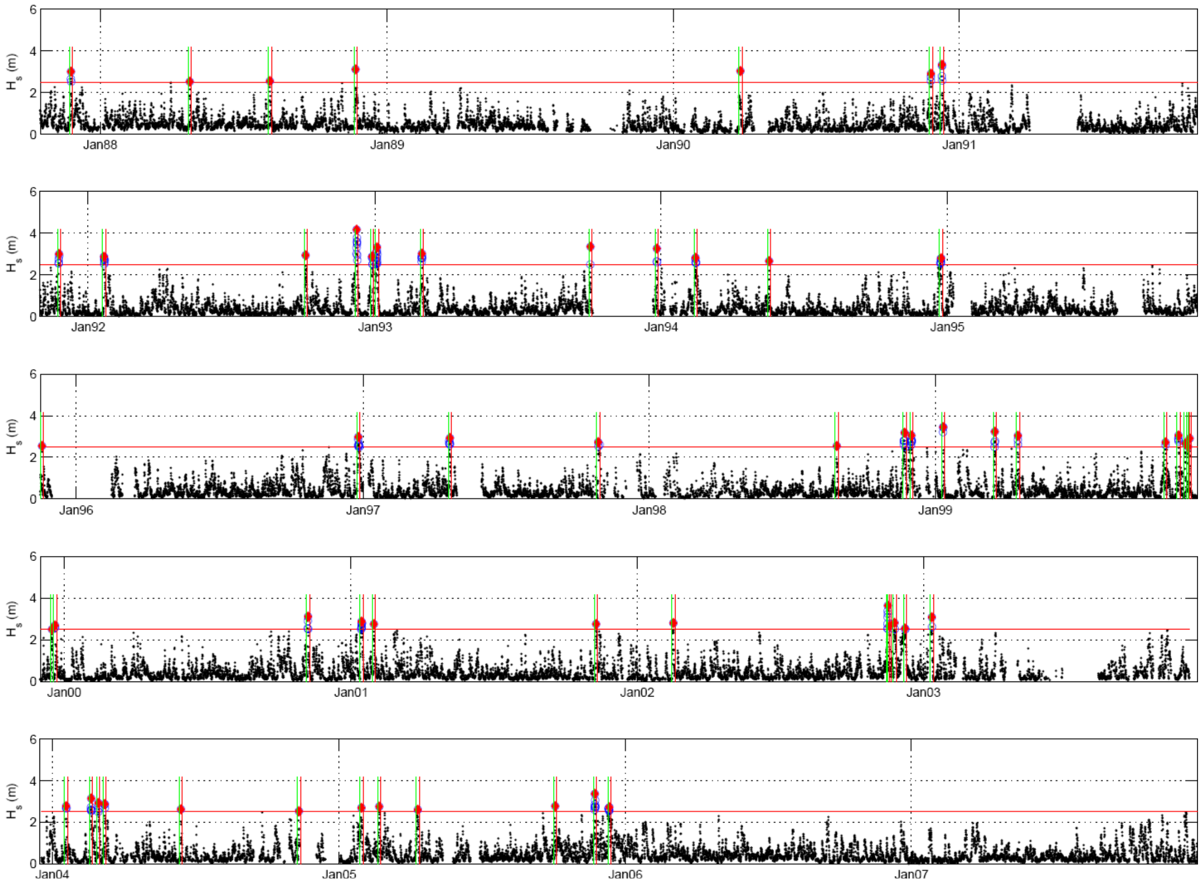


Figure 2.4.16 - POT method, data selection (omnidirectional)

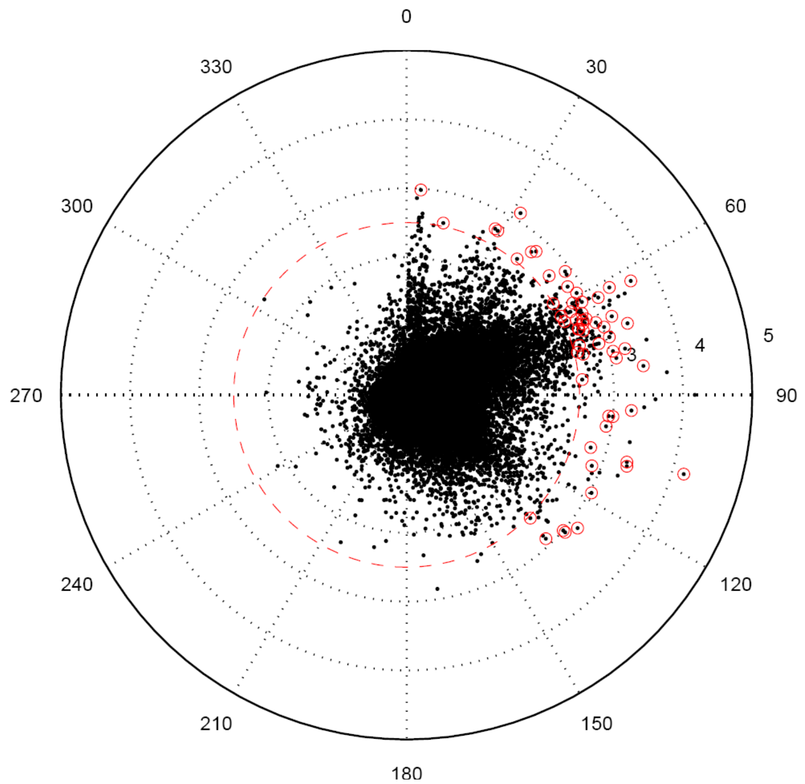


Figure 2.4.17 - Scatter plot and extreme wave events (omnidirectional)

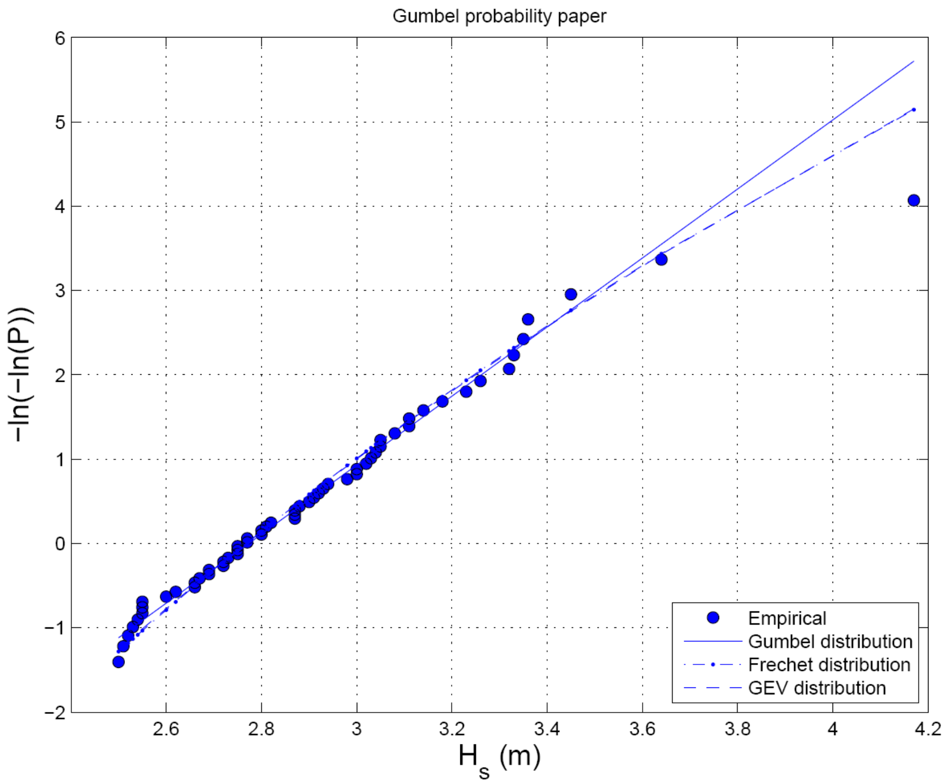


Figure 2.4.18 - PDF fitting (omnidirectional)

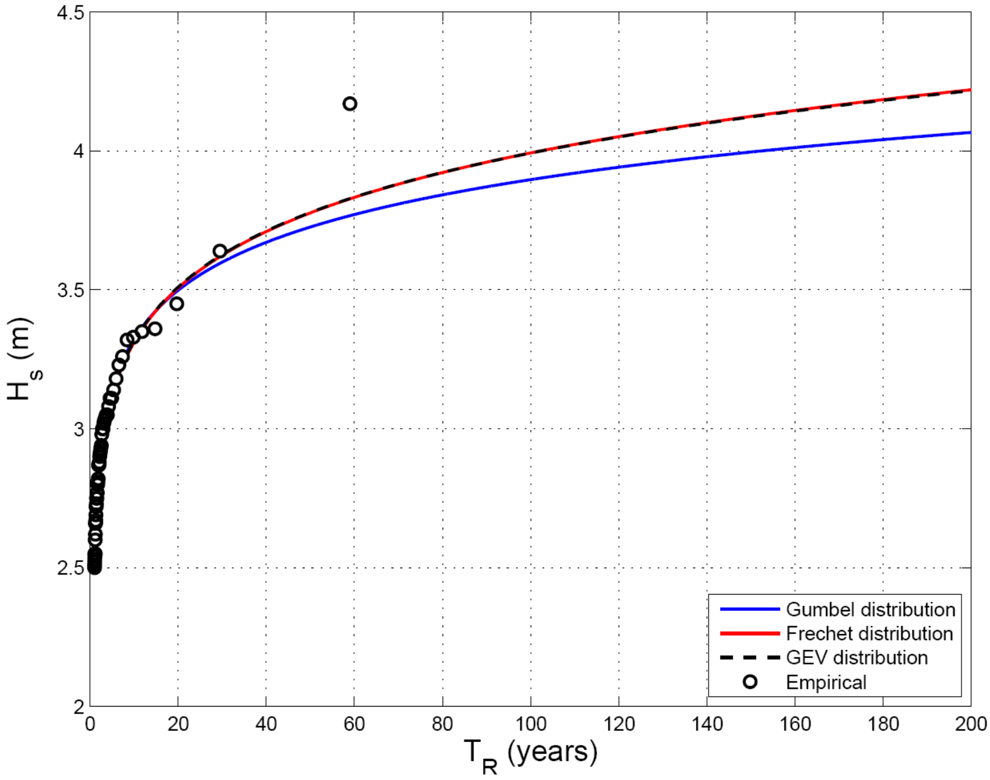


Figure 2.4.19 - Estimate of the significant wave height as a function of the return period (omnidirectional)

TR	Hs (m) Gumbel	Hs (m) Frechet	Hs (m) GEV
1.1	2.56	2.58	2.58
10	3.32	3.31	3.31
20	3.50	3.51	3.51
30	3.60	3.62	3.63
50	3.73	3.78	3.78
100	3.90	3.99	3.99
150	4.00	4.12	4.12
200	4.07	4.22	4.22

Table 2.4.12 - Estimate of the significant wave height as a function of the return period (omnidirectional)

The same procedure was used to separately analyse the data owning to the BORA and SCIROCCO angular sectors. The wave height thresholds for both BORA and SCIROCCO wave analysis were fixed to 2.5 m.

Figures 2.4.20 and 2.4.21 show the fitting with the above mentioned three PDFs (i.e. Gumbel, Frechet and GEV). Also in these cases the GEV distribution seems to better fit the empirical observations. Figures 2.4.22 and 2.4.23 describe the extrapolation procedure and provide the design wave height as a function of the return period for BORA and SCIROCCO respectively. Similarly Tables 2.4.13 and 2.4.14 synthesise the statistical parameters.

It is worth to remark that too many extreme events are available to allow a quite robust analysis especially for SCIROCCO, therefore the analysis may be affected by uncertainty.

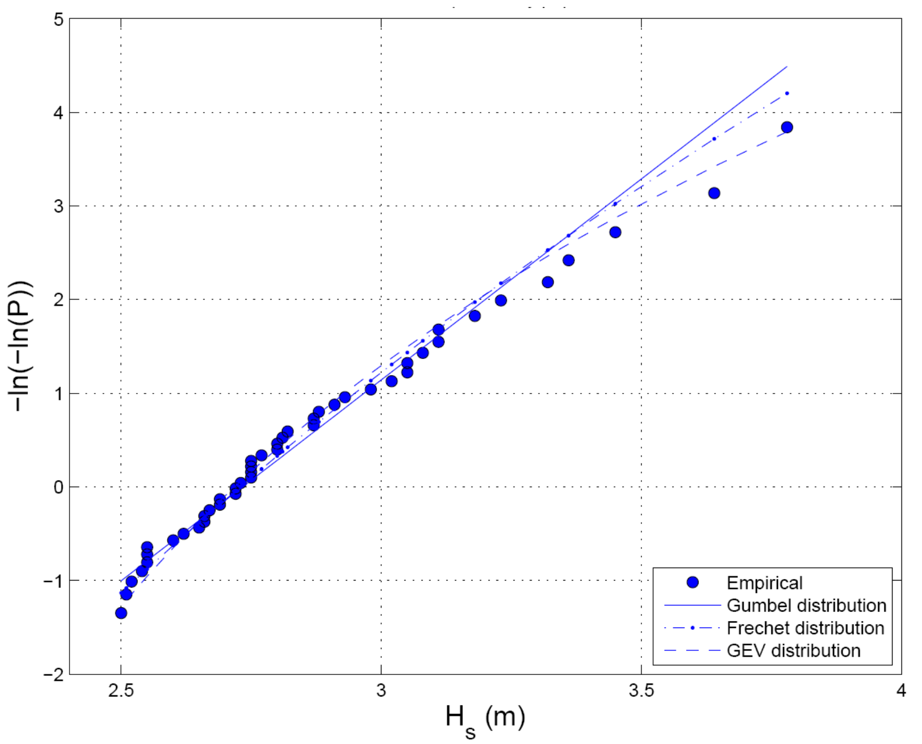


Figure 2.4.20 - PDF fitting (BORA)

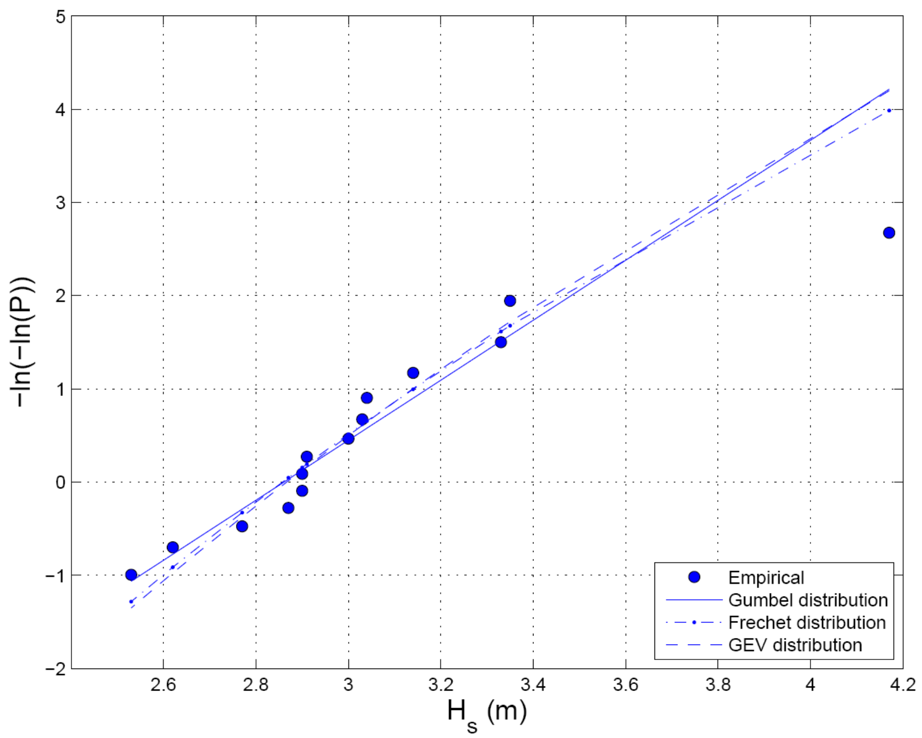


Figure 2.4.21 - PDF fitting (SCIROCCO)

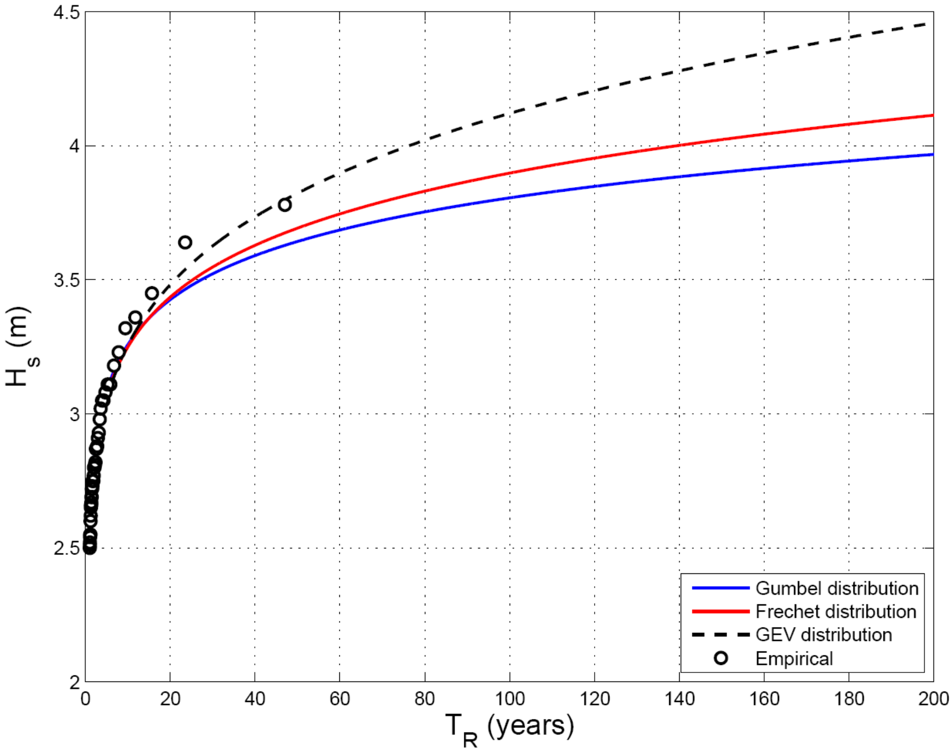


Figure 2.4.22 - Estimate of the significant wave height as a function of the return period (BORA)

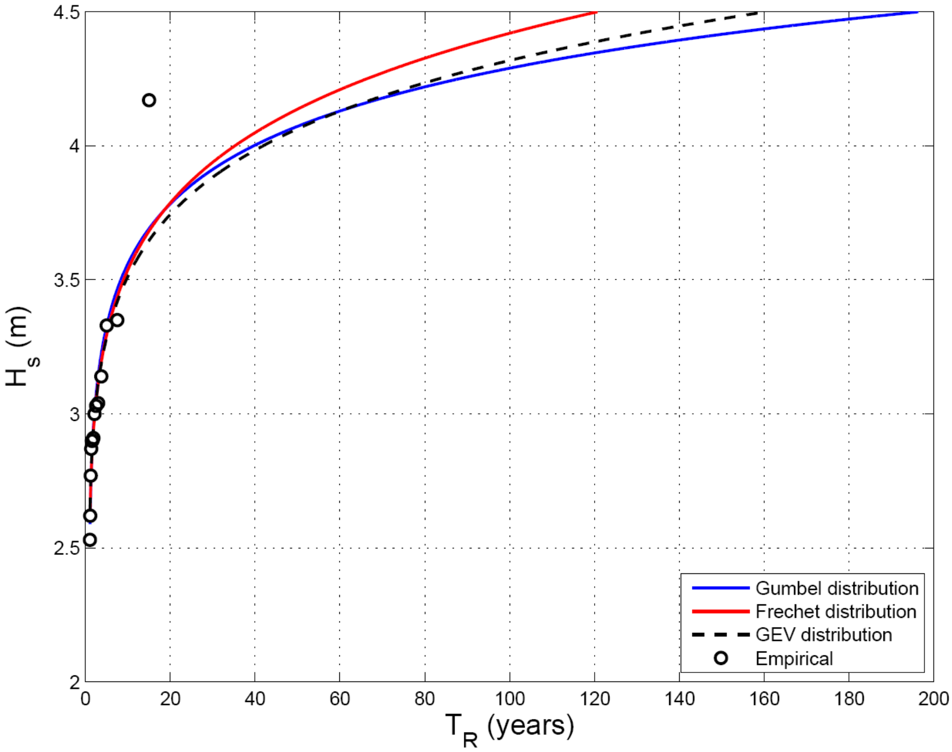


Figure 2.4.23 - Estimate of the significant wave height as a function of the return period (SCIROCCO)

TR	Hs (m) Gumbel	Hs (m) Frechet	Hs (m) GEV
1.1	2.53	2.55	2.56
10	3.26	3.25	3.26
20	3.43	3.44	3.48
30	3.52	3.55	3.63
50	3.64	3.69	3.82
100	3.81	3.90	4.12
150	3.90	4.02	4.31
200	3.97	4.11	4.46

Table 2.4.13 - Estimate of the significant wave height as a function of the return period (BORA)

TR	Hs (m) Gumbel	Hs (m) Frechet	Hs (m) GEV
1.1	2.59	2.63	2.64
10	3.56	3.54	3.51
20	3.78	3.79	3.74
30	3.91	3.94	3.88
50	4.07	4.14	4.06
100	4.29	4.42	4.32
150	4.42	4.59	4.47
200	4.51	4.72	4.59

Table 2.4.14 - Estimate of the significant wave height as a function of the return period (SCIROCCO)

Data analysis: Wind

The wind measurements, collected at the Acqua Alta Tower, cover a period from 1987 up to 2008. Figure 2.4.24 shows the time series of the wind speed Vw that occurred in the measurement period. It is worth to mention that, rather than the wave measurements, there is a lack in the wind data. Nevertheless the time series can be considered long enough to infer data analysis (i.e. mean and extreme wind regime).

In order to assess the mean annual wind regime, Figure 2.4.25 represents the frequency/direction/intensity diagram (i.e. rose diagram). Wind velocities, as well as, wind directions have been divided into classes.. The rose diagram clearly shows that at least two main directions appear; nevertheless, The BORA direction is dominating, both in intensity and frequency. Note that the same angular sections defined for the waves are used in the wind analysis.

Figure 2.4.26 confirms the identifications of the prevailing and the secondary directions. It is worth to highlight that the highest wind velocities clearly come from the BORA direction.

The typical annual wind conditions are also synthesised in Table 2.4.15.

As far as the wind energy conversion, by means of wind turbines, is considered, it is essential to provide the wind duration curve (see Figure 2.4.27).

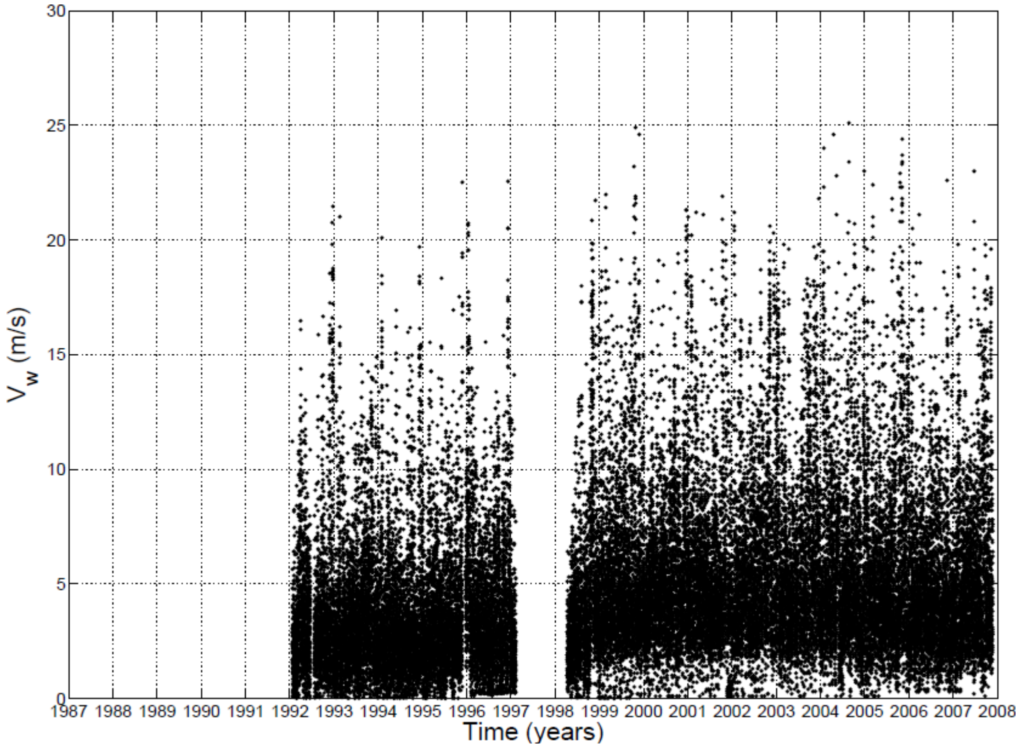


Figure 2.4.24. Time series of wind velocity (measurements since 1987 up to 2008)

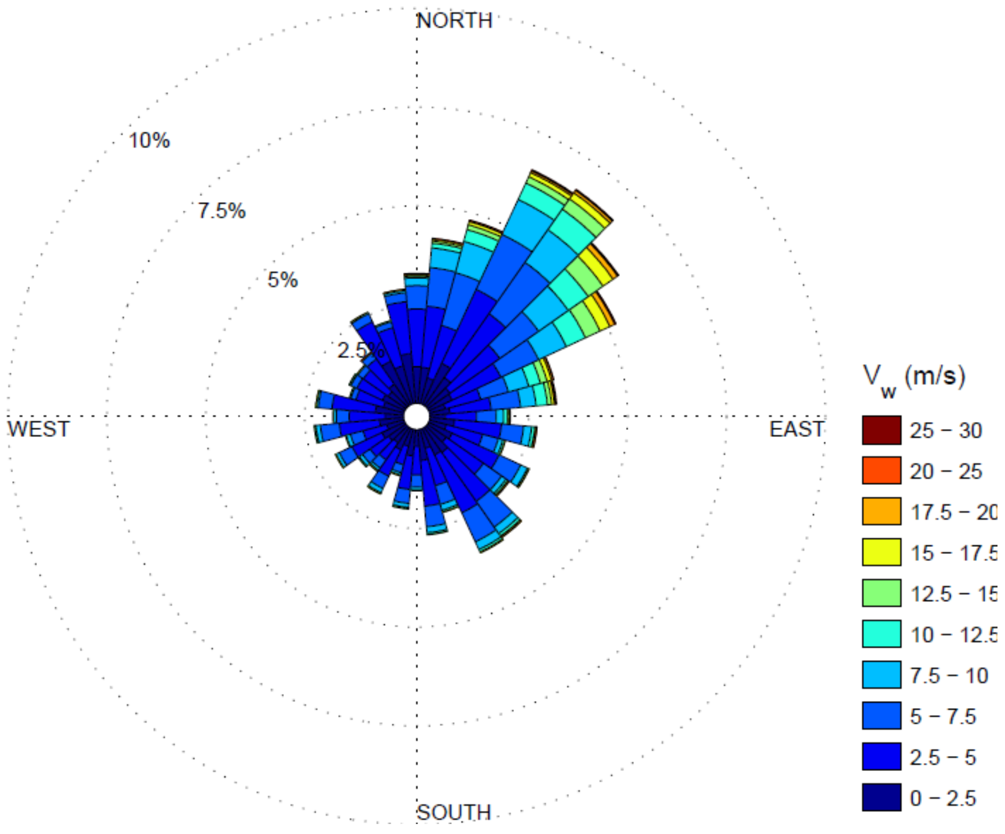


Figure 2.4.25. Mean annual wind regime (rose diagram)

DIR\V	0 - 2.5 m/s	2.5 - 5 m/s	5 - 7.5 m/s	7.5 - 10 m/s	10 - 12.5 m/s	12.5 - 15 m/s	15 - 17.5 m/s	17.5 - 20 m/s	20 - 25 m/s	25 - 30 m/s	
0° - 10°	0.884	1.376	0.684	0.296	0.058	0.041	0.039	0.01	0.01	0.00	**3.40**
10° - 20°	0.814	1.583	1.239	0.627	0.181	0.077	0.046	0.02	0.00	0.00	**4.60**
20° - 30°	0.817	1.429	1.400	0.884	0.398	0.161	0.106	0.03	0.02	0.00	**5.25**
30° - 40°	1.166	2.422	1.692	1.048	0.528	0.231	0.137	0.05	0.03	0.00	**7.30**
40° - 50°	0.754	1.569	1.345	0.964	0.634	0.378	0.234	0.11	0.03	0.00	**6.02**
50° - 60°	0.733	1.641	1.207	0.867	0.624	0.443	0.320	0.13	0.04	0.00	**6.00**
60° - 70°	0.511	1.046	0.913	0.655	0.402	0.325	0.210	0.11	0.01	0.00	**4.19**
70° - 80°	0.477	1.082	0.761	0.569	0.373	0.149	0.111	0.03	0.03	0.00	**3.59**
80° - 90°	0.455	0.822	0.571	0.227	0.142	0.060	0.029	0.01	0.01	0.00	**2.33**
90° - 100°	0.431	0.865	0.537	0.159	0.084	0.041	0.027	0.00	0.00	0.00	**2.14**
100° - 110°	0.593	1.212	0.487	0.181	0.082	0.014	0.005	0.00	0.00	0.00	**2.58**
110° - 120°	0.477	0.928	0.429	0.145	0.048	0.002	0.005	0.00	0.00	0.00	**2.03**
120° - 130°	0.682	1.427	0.658	0.188	0.041	0.012	0.005	0.00	0.00	0.00	**3.01**
130° - 140°	0.706	1.296	0.595	0.166	0.058	0.043	0.002	0.00	0.00	0.00	**2.87**
140° - 150°	0.829	1.740	0.942	0.210	0.094	0.036	0.002	0.00	0.00	0.00	**3.86**
150° - 160°	0.501	1.181	0.631	0.169	0.055	0.005	0.005	0.00	0.00	0.00	**2.55**
160° - 170°	0.795	1.236	0.593	0.181	0.046	0.007	0.002	0.00	0.00	0.00	**2.86**
170° - 180°	0.489	0.800	0.330	0.104	0.031	0.005	0.000	0.00	0.00	0.00	**1.76**
180° - 190°	0.475	0.658	0.284	0.077	0.007	0.002	0.000	0.00	0.00	0.00	**1.50**
190° - 200°	0.636	0.788	0.306	0.080	0.048	0.002	0.000	0.00	0.00	0.00	**1.86**
200° - 210°	0.398	0.542	0.239	0.082	0.017	0.005	0.002	0.00	0.00	0.00	**1.28**
210° - 220°	0.680	0.735	0.364	0.123	0.024	0.005	0.007	0.00	0.00	0.00	**1.94**
220° - 230°	0.443	0.496	0.222	0.065	0.019	0.010	0.000	0.00	0.00	0.00	**1.26**
230° - 240°	0.663	0.829	0.337	0.111	0.019	0.002	0.000	0.00	0.00	0.00	**1.96**
240° - 250°	0.496	0.629	0.287	0.092	0.005	0.007	0.002	0.00	0.00	0.00	**1.52**
250° - 260°	0.564	0.805	0.429	0.120	0.029	0.010	0.000	0.00	0.00	0.00	**1.96**
260° - 270°	0.516	0.928	0.424	0.084	0.029	0.007	0.000	0.00	0.00	0.00	**1.99**
270° - 280°	0.511	0.918	0.292	0.055	0.007	0.005	0.000	0.00	0.00	0.00	**1.79**
280° - 290°	0.704	1.077	0.280	0.046	0.007	0.000	0.002	0.00	0.00	0.00	**2.12**
290° - 300°	0.559	0.651	0.125	0.027	0.007	0.005	0.000	0.00	0.00	0.00	**1.37**
300° - 310°	0.624	0.747	0.193	0.041	0.010	0.000	0.000	0.00	0.00	0.00	**1.61**
310° - 320°	0.564	0.771	0.154	0.005	0.007	0.000	0.002	0.00	0.00	0.00	**1.50**
320° - 330°	0.942	0.949	0.224	0.039	0.002	0.000	0.000	0.00	0.00	0.00	**2.16**
330° - 340°	1.077	0.988	0.200	0.027	0.000	0.000	0.002	0.00	0.00	0.00	**2.29**
340° - 350°	1.113	1.072	0.142	0.027	0.012	0.002	0.000	0.00	0.00	0.00	**2.37**
350° - 360°	1.137	1.518	0.359	0.099	0.036	0.012	0.000	0.01	0.00	0.00	**3.17**
	24.22	**38.75**	**19.87**	**8.84**	**4.17**	**2.11**	**1.30**	**0.53**	**0.20**	**0.00**	**100.00**

Table 2.4.15. Mean annual wind regime

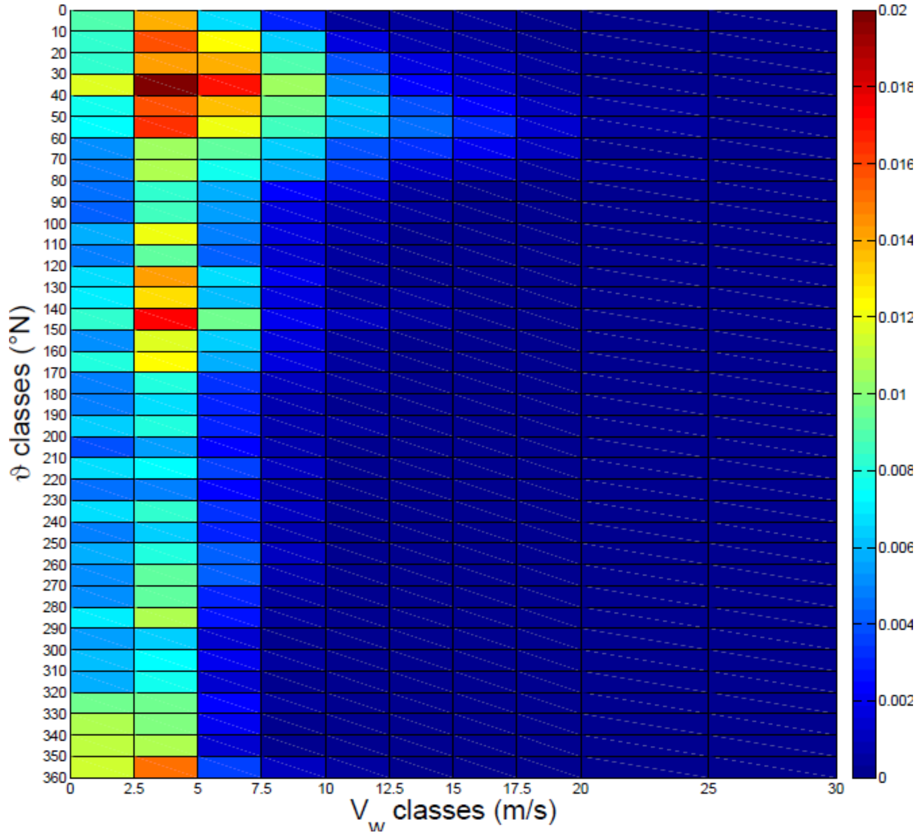


Figure 2.4.26. Annual wind regime.

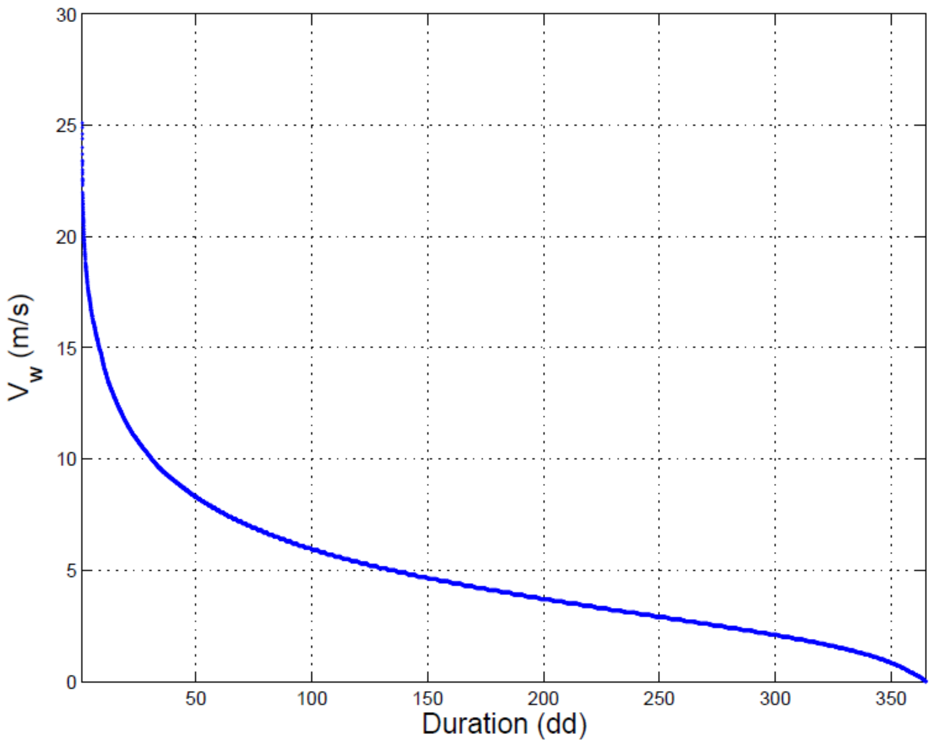


Figure 2.4.27. Wind duration curve.

Extreme values analysis: Wind

Aiming at providing the wind design parameters the extreme values analysis has been carried out. It has to be stressed that two extreme wind analysis have been carried:

- Omnidirectional extreme value analysis;
- extreme value analysis for the angular sector BORA.

Similarly to what already done for waves, the POT methods was used, by adopting a wind velocity threshold equal to 20.0 m/s. Figure 2.4.28 shows the results of the selection procedure. The red dots identify the homogeneous and statistically independent extreme events to be used. Figure 2.4.29 shows by means of a scatter plot the extreme events (red circles), while the red dashed line identify the wave height threshold.

In order to choose the probability density function (hereinafter PDF), three PDFs were used, namely that of Gumbel, Frechet and GEV, see Fig. 2.4.30. It is possible to see that none of the the theoretical PDFs seems to fit exactly the empirical data. Nevertheless the Frechet distribution can represent a good choice to fit the empirical observations. Figure 2.4.31 and Table 2.4.16 describe the extrapolation procedure and provide the design wave height as a function of the return period.

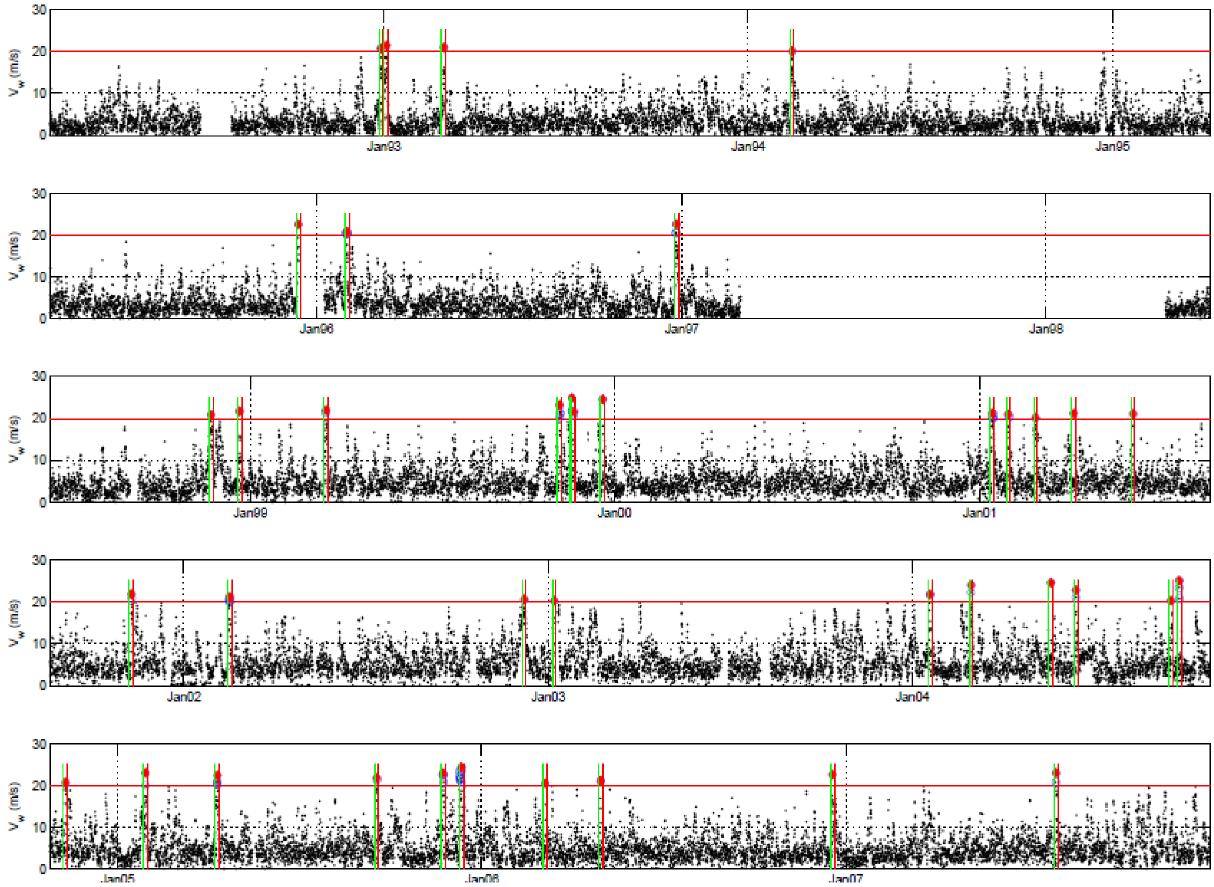


Figure 2.4.28. POT method, data selection (omnidirectional)

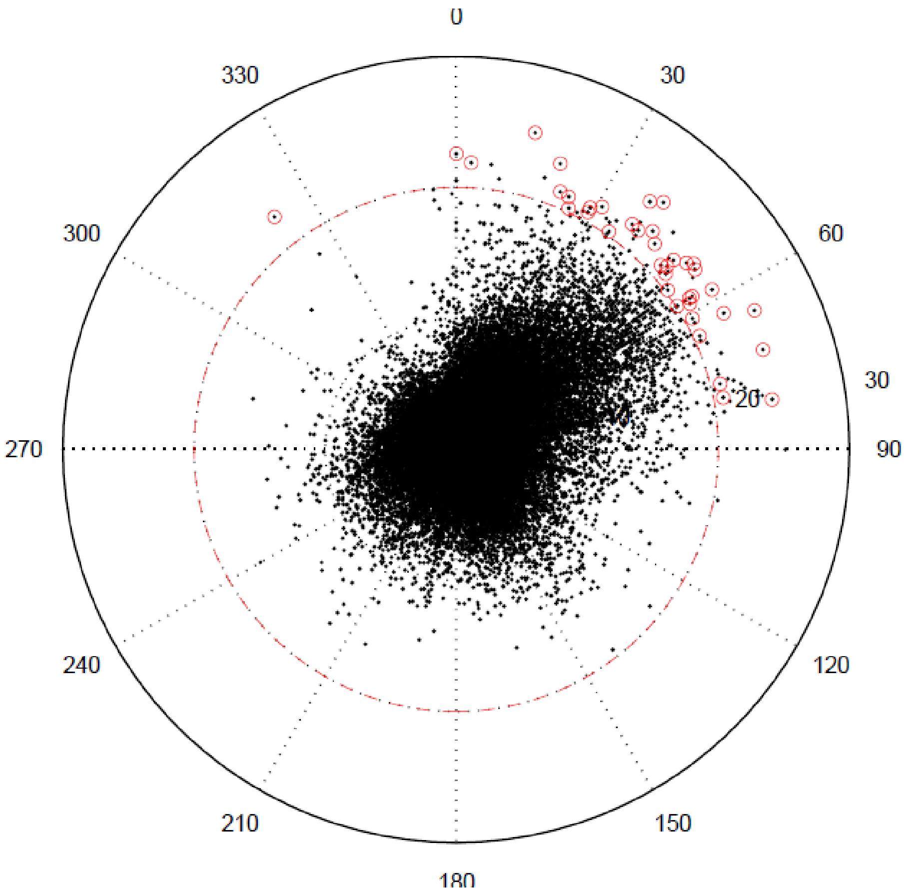


Figure 2.4.29 - Scatter plot and extreme wind events (omnidirectional)

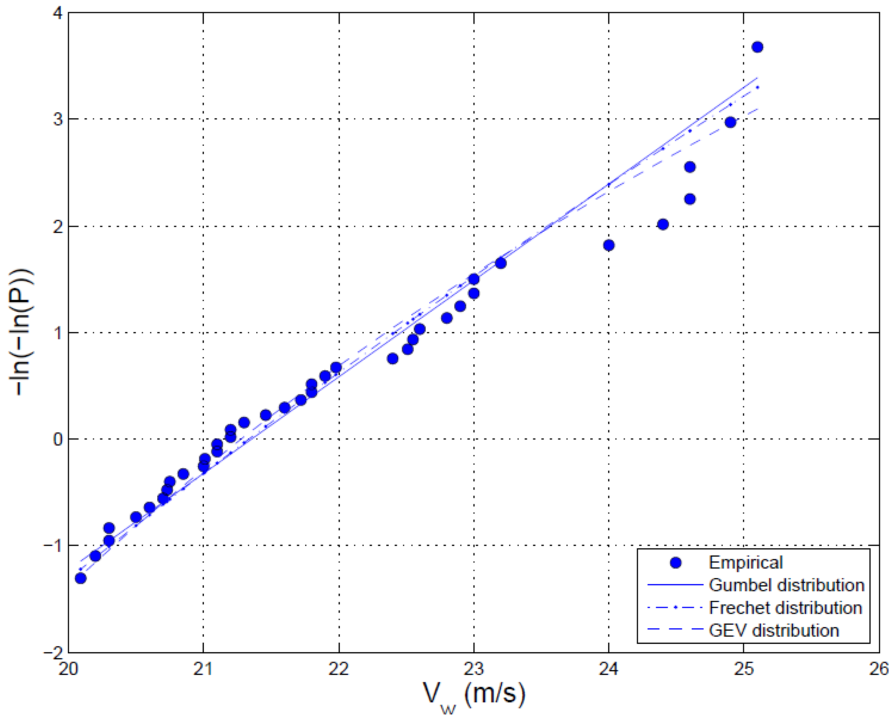


Figure 2.4.30 - PDF fitting (omnidirectional)

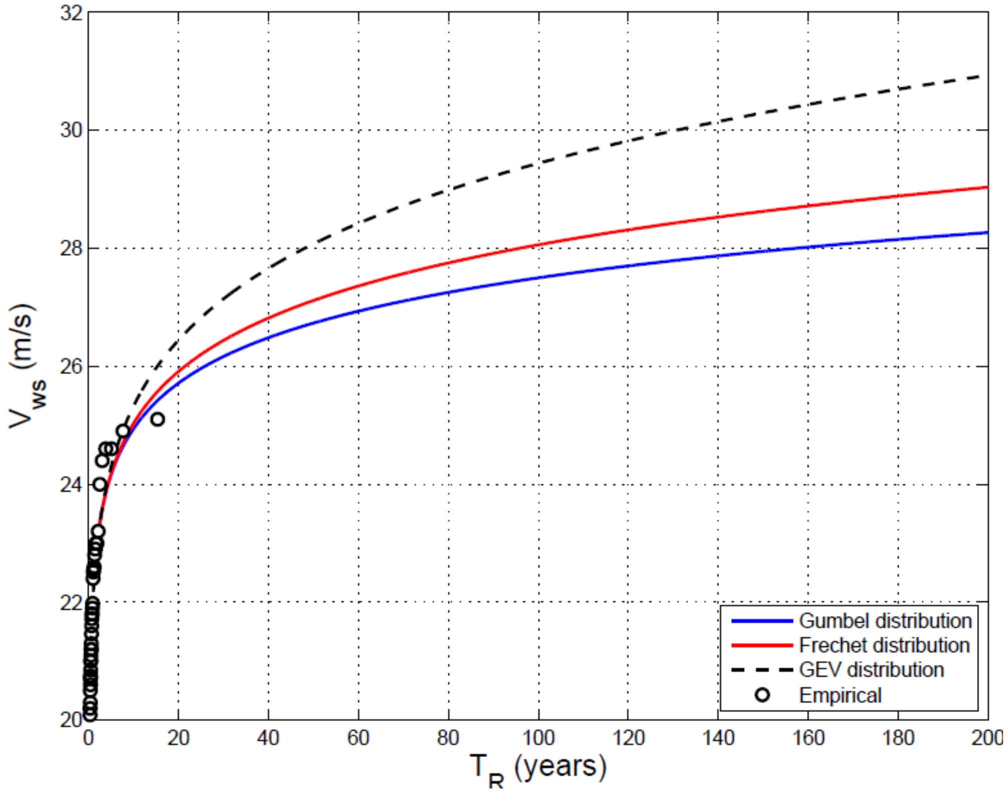


Figure 2.4.31 - Estimate of the significant wind velocity as a function of the return period (omnidirectional)

TR	Vw (m) Gumbel	Vw (m) Frechet	Vw (m) GEV
1.1	22.29	22.24	22.17
10	24.93	25.03	25.32
20	25.71	25.91	26.44
30	26.16	26.44	27.14
50	26.73	27.11	28.07
100	27.50	28.06	29.44
150	27.95	28.63	30.30
200	28.27	29.03	30.93

Table 2.4.16 - Estimate of the significant wind velocity as a function of the return period (omnidirectional)

The same procedure was used to analyse the data owning to the BORA angular sector. The wind velocity threshold for the BORA wind analysis was fixed to 20.0 m/s as well.
Figure 2.4.32 show the fitting of the extreme data with the above mentioned three PDFs (i.e. Gumbel, Frechet and GEV). Again the Frechet distribution provides the best fitting of the empirical observations. Figure 2.4.33 and Table 2.4.17 describe the extrapolation procedure and provide the design wave height as a function of the return period.

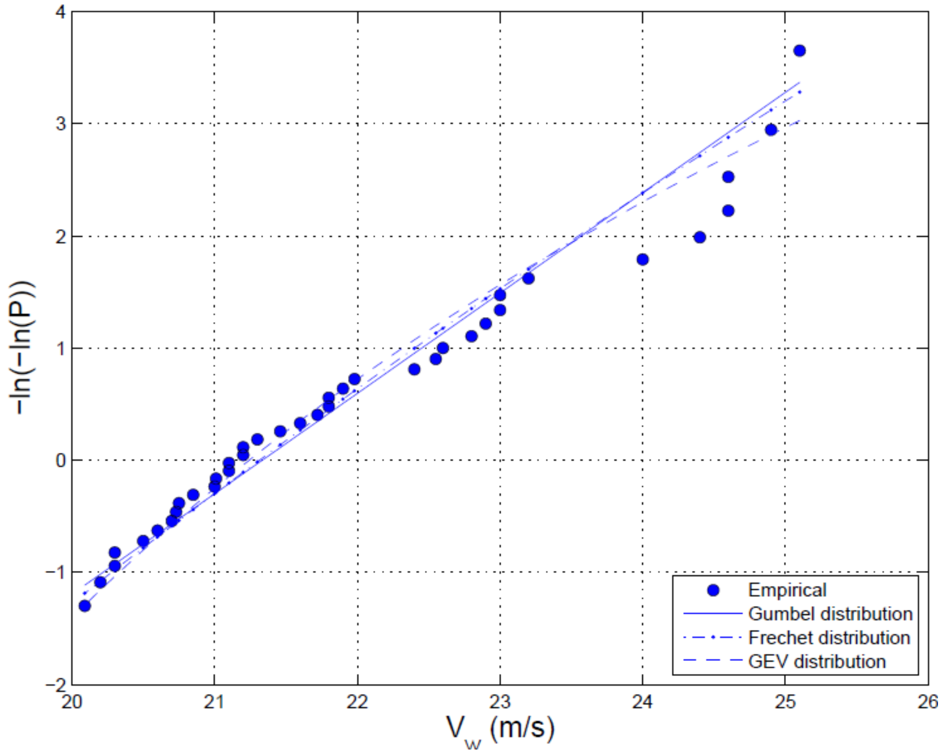


Figure 2.4.32 - PDF fitting (BORA)

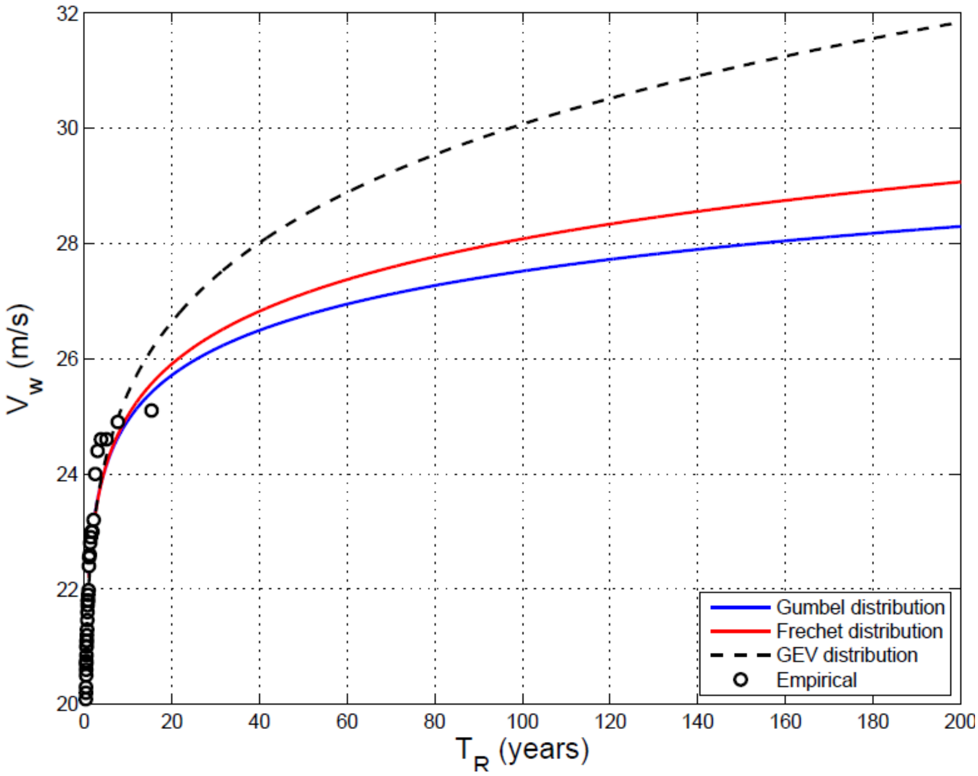


Figure 2.4.33 - Estimate of the significant wind velocity as a function of the return period (BORA)

TR	Vw (m) Gumbel	Vw (m) Frechet	Vw (m) GEV
1.1	22.24	22.19	22.10
10	24.93	25.01	25.40
20	25.71	25.91	26.64
30	26.17	26.44	27.42
50	26.74	27.12	28.49
100	27.52	28.08	30.07
150	27.97	28.65	31.08
200	28.30	29.07	31.84

Table 2.4.16 -. Estimate of the significant wind velocity as a function of the return period (BORA)

2.4.4 **Hydro-morphological analysis**

SAR images were processed to derive the fields of wind and waves useful for the analysis of meteorological and marine data. The fields of wind and waves were estimated using the GWW software, developed by e-GEOS and can extract fields of wind and waves from SAR images of the sensors ENVISAT-ASAR, RADARSAT-1/2 and COSMO-SkyMed.
The dataset (Table 2.4.17) used for the present study consists of 16 satellite images. SAR images are distributed as follows: 10 COSMO-SkyMed images; 5 ENVISAT-ASAR images; RADARSAT-1 image 2.

Sensor	*Sensor Mode*	*Date gg/mm/aa*	*H UTC hh:mm:ss*	*Resolz. (m)*	*Polariz.*	*Look angle**
COSMO-SkyMed	StripMap HIMAGE	17/07/11	17:19:32	5	H/H	RD
COSMO-SkyMed	StripMap HIMAGE	14/11/11	17:18:27	5	H/H	RD
ENVISAT-ASAR	Precision Image	20/01/12	09:20:12	30	H/H	RD
COSMO-SkyMed	StripMap HIMAGE	20/01/12	17:23:46	5	H/H	RD
COSMO-SkyMed	StripMap HIMAGE	20/01/12	17:23:51	5	H/H	RD
COSMO-SkyMed	StripMap HIMAGE	25/01/12	17:17:45	5	H/H	RD
COSMO-SkyMed	StripMap HIMAGE	25/01/12	17:17:49	5	H/H	RD
COSMO-SkyMed	StripMap HIMAGE	25/01/12	17:17:54	5	H/H	RD
ENVISAT-ASAR	Wide Swath Mode	25/01/12	20:53:15	150	V/V	RA
COSMO-SkyMed	StripMap HIMAGE	28/01/12	04:50:18	5	H/H	RA
ENVISAT-ASAR	Wide Swath Mode	30/01/12	21:09:27	150	V/V	RA
ENVISAT-ASAR	Wide Swath Mode	02/02/12	20:59:34	150	V/V	RA
ENVISAT-ASAR	Wide Swath Mode	05/02/12	09:33:00	150	V/V	RD
COSMO-SkyMed	StripMap HIMAGE	10/02/12	17:17:35	5	H/H	RD
RADARSAT-2	Fine Quad-pol		17:06:53	11x9	H+V/H+V	RA
COSMO-SkyMed	StripMap HIMAGE		17:09:55	5	V/V	RD

**RA = Right Ascending; RD = Right Desceding*

Table 2.4.17 - Number of images of the dataset and their main characteristics. The colors distinguish the four main periods taken into account in this study.

Acronyms used in the following are

- ECMWF European Centre for Medium-Range Weather Forecasts
- GWW Global Wind and Wave
- OGCM Ocean General Circulation Model
- SAR Synthetic Aperture Radar
- TeMAS® Telespazio Maritime Applications from SAR

For this analysis, the following data meteorological and marine were analyzed:

- data of wind and sea state of the station CNR-ISMAR Acqua Alta (45 ° 18'51" E-12 ° 30'30" N);
- wind data of the meteorological model of the European Centre for Medium-Range Weather Forecasts (ECMWF);
- fields of wind and waves dall'immagini SAR obtained with the help of the GWW software developed by e-GEOS;
- surface currents and transport of Stokes of the model OGCM of the National Institute of Geophysics and Volcanology - Bologna;
- values of Sea Surface Temperature (SST) derived from MODIS multispectral images of the TERRA satellite.

In the case of transport by means of the current and wind, it can be seen also as a weak surface current of 1 cm / s (0.01 m/s) and a wind of 5 m/s can be covered by the substance dispersed in the surface a distance of about 13-14 km per day.

The wind data platform Acqua Alta ISMAR and weather forecasts of the ECMWF 24-26 January 2012 show that the wind changed direction going from West and North-Northwest to North, and finally to the North-Northeast (see Fig. 2.4.34). The wind speed was about 2-3 m / s. Wind from the East then persisted for several days after that of the stranding.
Between 24 and 26 January 2012 the transport of Stokes, predicted by the model OGCM, had steadily towards the South-West, moving toward the coast with an average speed of 4 cm / s approximately (Fig. 2.4.34). Also the transport of Stokes, as well as the wind, after January 27, retained the same direction for many days, increasing in intensity thanks to bora that was blowing in those days.
On 17/02/2012, the wind blow with high speed, due to the bora, for many days (from 27 January) from North-East, until 14/02/2012. From February 14 to 17 changed direction several times, but blew mainly from the North and West. The transport of Stokes predicted by the model OGCM basically follows the same trend, but on 17/02/2012 the current is directed towards the East-North-East with a speed of 3 cm / s or so (Fig. 2.4.35).

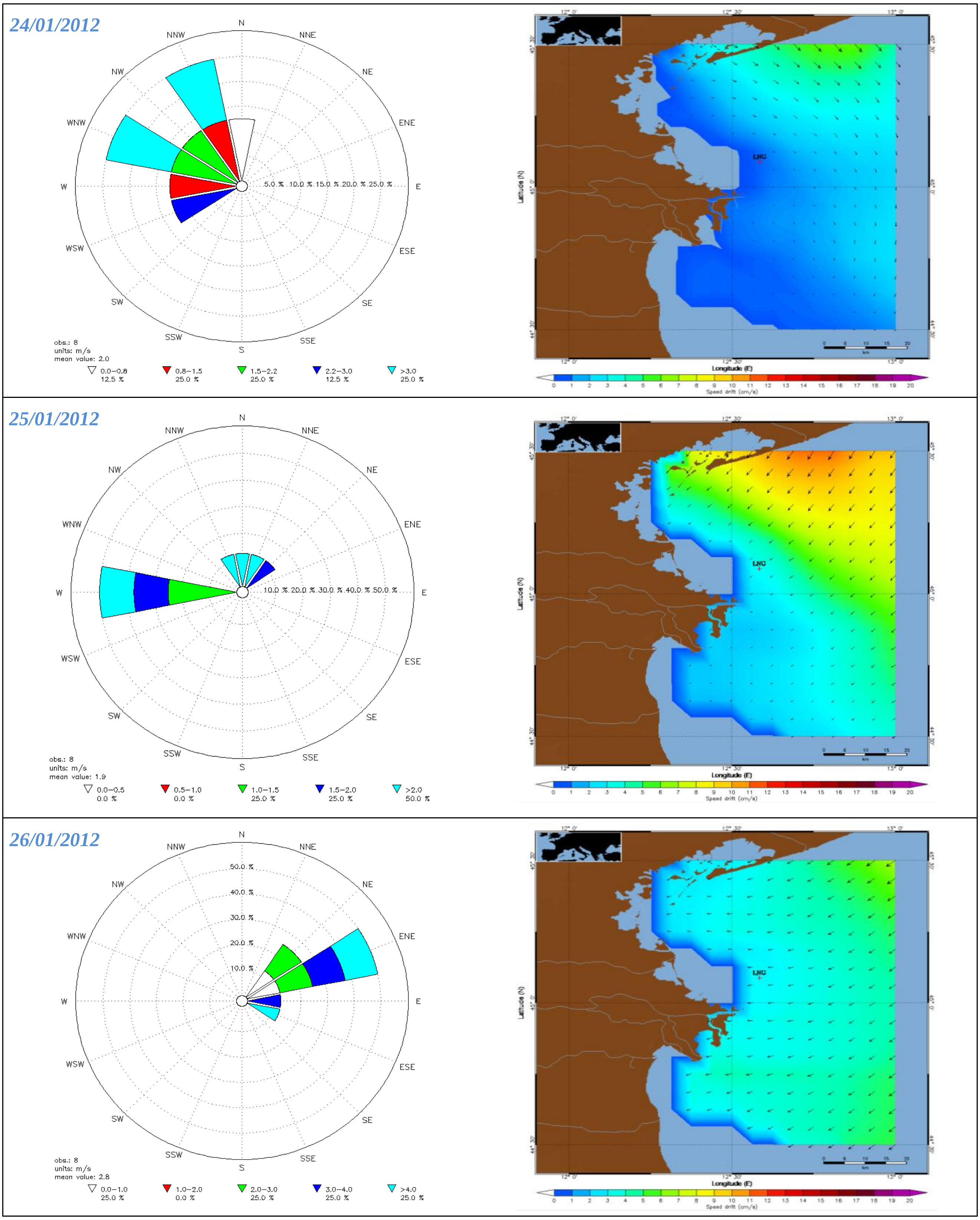


Figure 2.4.34. Rose of the Winds (Platform High Water) and the Stokes drift model OGCM.

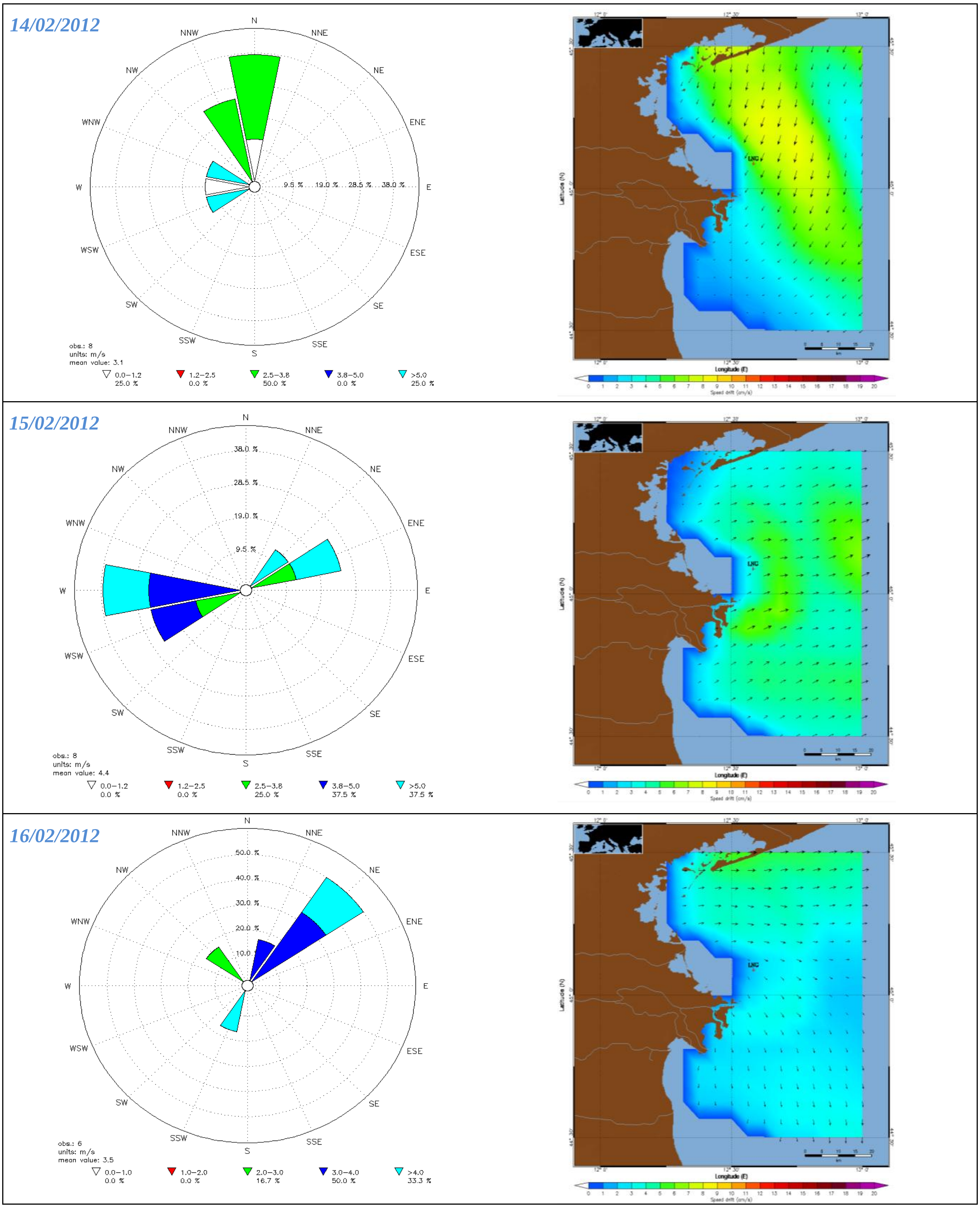


Figure 2.4.35. Rose of the Winds (Platform High Water) and the Stokes drift model OGCM.

As a second step optical images were processed to derive bio-physical parameters. Maps produced from Earth Observation optical products show spatial distribution of bio-physical parameters for the North Adriatic study site. From MERIS and MODIS optical sensors, on- board satellite platforms, has been possible to retrieve spatial distributed maps of the following parameters: SST (Sea Surface Temperature); Chl-a (Chlorophyll); CDOM (Colored Dissolved Organic Matter); TSM (Total Suspended Matter); Kd490 (Diffuse attenuation coefficient for downwelling irradiance at 490 nm).
Earth Observation product maps are used for both validation and calibration of hydrodynamic and ecological models, by providing quantitative and qualitative spatial distributed information.
Spatio-temporal analysis of bio-physical parameters will supply the environmental characterization with analytical data.
Spatial resolution of maps is 300 m to 1 Km while temporal resolution is dependent on cloud coverage (varying daily to monthly).

Po river plume distribution is clearly visible from Earth Observation products, and generally is driven by Western Adriatic Current (WAC), which flows South-Eastward along the Italian coast. In particular, TSM maps shows spatial distribution of sediment driven by circulation currents, as well as quantitative estimation (0.2 to 20.0 g/m-3), see Fig. 2.4.36.
Bio-optical properties of waters, investigated by means of remotely sensed data, shows high chlorophyll concentration (0.1 to 10 g/m-3), see Fig. 2.4.36. Based on a bio-optical point of view, North Adriatic waters can be classified as Case 2 waters.
Kd490 maps will support seabed morphodynamics assessment by evaluating the area influenced by particle re-suspension rate and transport during extreme events.

2.4.5 **Environmental characterization**

The North Adriatic is a shallow, semi-enclosed, basin with an average slope of 0.35 m/km and an average depth of 40 m. As a consequence of these bathymetric characters the basin displays a very peculiar circulation pattern, high seasonal variability, sharp stratification and very high productivity rates (Artioli et al. 2005). The general circulation is cyclonic (counter-clockwise), highly variable with seasons, and mainly driven by the prevalent winds (NE and SE) and by the freshwater discharge from rivers (Artegiani et al. 1997) among which the most important is the Po river. The surface temperature excursion between summer and winter is more than 15 °C (Fig. 2.4.38) and the net annual mean water balance is positive due to the river runoff contribution while the annual mean heat budget is negative due to the large winter heat losses in the Northern Adriatic (Wang and Pinardi 2002). The meteoclimatology of the area presents strong north-easterly winds during winter (Bora), while during summer and autumn winds are generally south-easterly at smaller amplitude (Scirocco). The large-scale wind- and thermohaline-driven currents experience large seasonal excursions due to all these forcing. During spring and summer the northern basin warms up from top to bottom and a well- defined seasonal thermocline forms (Fig. 2.4.38). The seasonal pycno-cline is large due to the additional contribution of the river run-off.
The Po River discharges at an annual average rate of 1700 m^3s^{-1} and it is a fundamental controlling factor on the basin hydrodynamics (Wang and Pinardi 2002)

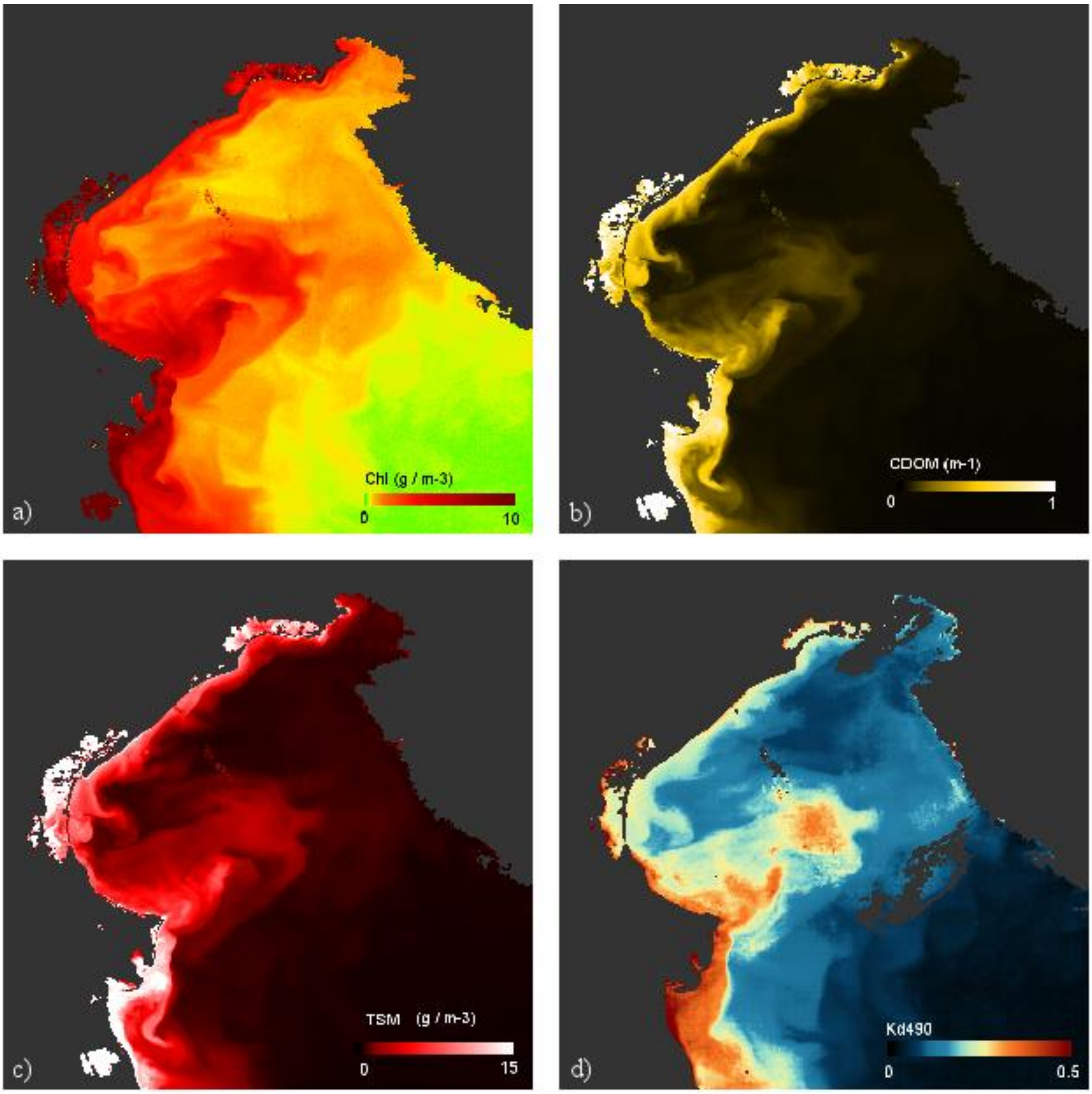


Figure 2.4.37: Map retrieved from MERIS sensor onboard ENVISAT satellite (acquired on 05 May 2011) showing spatial distribution of the following parameters: a. Chlorophyll concentration (g/m-3); b. Colored Dissolved Organic Matter (m-1); c. Total Suspended Matter (g/m-3); d. Diffuse attenuation coefficient for down-welling irradiance at 490 nm.

The Northern part of the study region is under the direct influence of the Po river plume, with important effects in terms of deposition of sediments and reduced salinity (Figure) from freshwater discharge (Artioli et al. 2005, Bever et al. 2009). Prevailing winds and circulation patterns affect the transport and distribution of the plume (Wang and Pinardi 2002). Bever et al. (2009) have shown that the plume is generally confined to the north of Ravenna, and that less than 5% is transported south of Cesenatico. There are also regional environmental discontinuities along an inshore-

offshore axis, related to differences in depth, wave-induced shear stress, sediment deposits and human impacts (Boldrin et al. 2005, Bever et al. 2009). In particular, a high contribution of wave-induced shear stress in shallow water was found inshore of the 20 m isobath, leading to high resuspension of sediments at shallow depths (Bever et al. 2009). Owing to river runoff and oceanographic conditions, the region also exhibits a decreasing trend of nutrient concentration and production from north to south and from west to east (Fonda Umani, 1996; Zavatarelli et al., 1998). The main seasonal variability in biogeochemical properties (dissolved oxygen, AOU, nitrate, phosphate, silicate and chlorophyll-a) are reported in Fig. 2.4.39a and 2.4.39b (from Zavatarelli et al.1998).
Following this preliminary assessment of the area, detailed sets of data should be acquired for the following parameters, so that a final assessment can be delivered from MEDAR / MEDATLAS II:
Temperature; Salinity; Oxygen; Nitrate, Nitrite, Nitrite•- Ammonia and Total Nitrogen; Phosphate and Total Phosphorus; Silicate;•H2S; pH•and Alkalinity•and Chlorophyll-a.
With an assessment periods and different years of some particular aspects such as:
- annual, seasonal and monthly climatology for temperature and salinity
- annual and seasonal climatology for oxygen, silicate and phosphate
- annual climatology for nitrate, nitrite, pH, ammonium, alkalinity and chlorophyll.

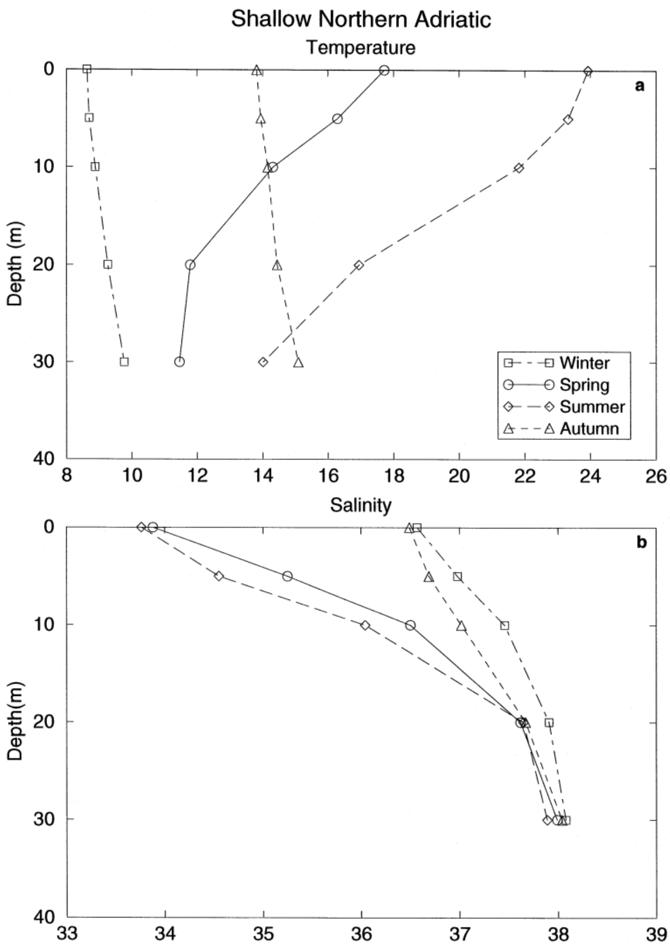


Figure 2.4.39a - Seasonal vertical profiles of temperature (°C); salinity (psu) for the shallow northern Adriatic (source Zavattarelli et al. 1998)

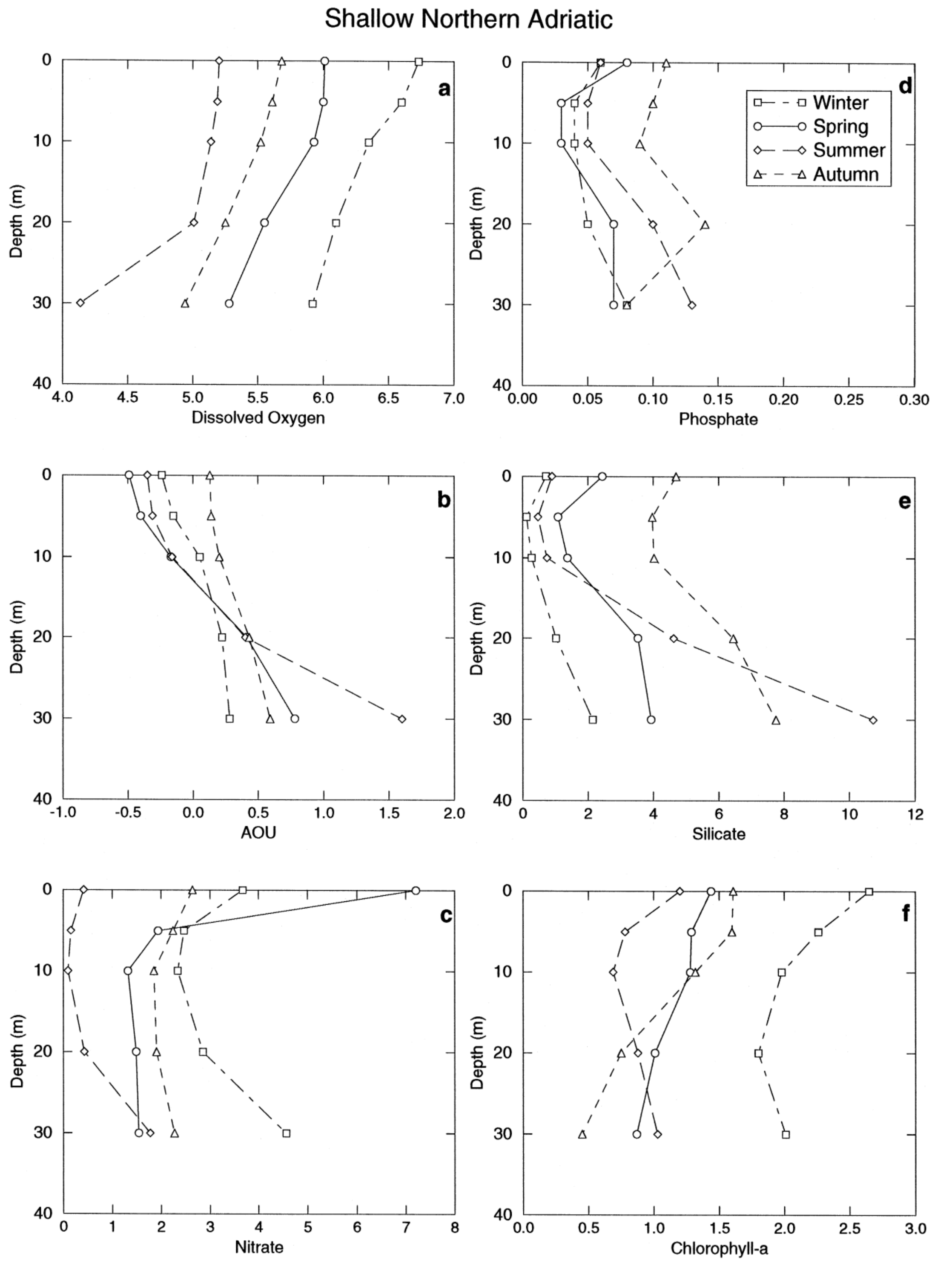


Figure 1.4.39b Seasonal vertical profiles of: a. dissolved oxygen (ml l^{-1}); b. AOU (ml l^{-1}); c. nitrate (mmol l^{-1}); d. phosphate (mmol l^{-1}); e. silicate (mmol l^{-1}); f. chlorophyll-a (mg l^{-1}); for the shallow northern Adriatic (source Zavatarelli et al. 1998)

Sediments comprise mainly mud, with an average fraction of coarser sediments (>63µm) generally lower than 8% dry wt (Abbiati et al unpublished data). Sites to the north tend to show a higher content in organic matter compared to sites to the south at similar depths. There are differences also between shallow (<20 m) and deep (>20 m) sites: the latter are characterized by a greater content of organic matter, and a lower content of coarse sediment (>63µm), while the former have a greater proportion of sand.

The Region presents a high diversity of environmental conditions that is translated into a high biodiversity (Ott 1992, Coll et al. 2007). Numerous studies describe the distribution and abundance of marine fauna and flora of the Adriatic Sea (e.g. (Zupanovic 1961, Zupanovic 1974, Jardas and Zupanovic 1980, Riedl 1986, Zupanovic and Jardas 1986). Information on habitat distributions in the region are however fragmented (Fig. 2.4.40). In the Region, at the mouths of the Po and close to Grado, there are also special areas called "tegnue" which are concretions of benthic organisms. In front of the coast of the city of Chioggia is located the complex of Tegnùe broader and more importantly, where there are larger groupings. “Tegnue” was building to a carbonate cementation of clastic sediments (sands) and to the presence of calcareous skeletons left, after their death, from plants and animals called, for this reason, 'builders' (one of the main may include calcareous algae *Peyssonneliaceace* and *Corallinaceae*, *cnidarians encrusting*, *serpulids* and bryozoans).

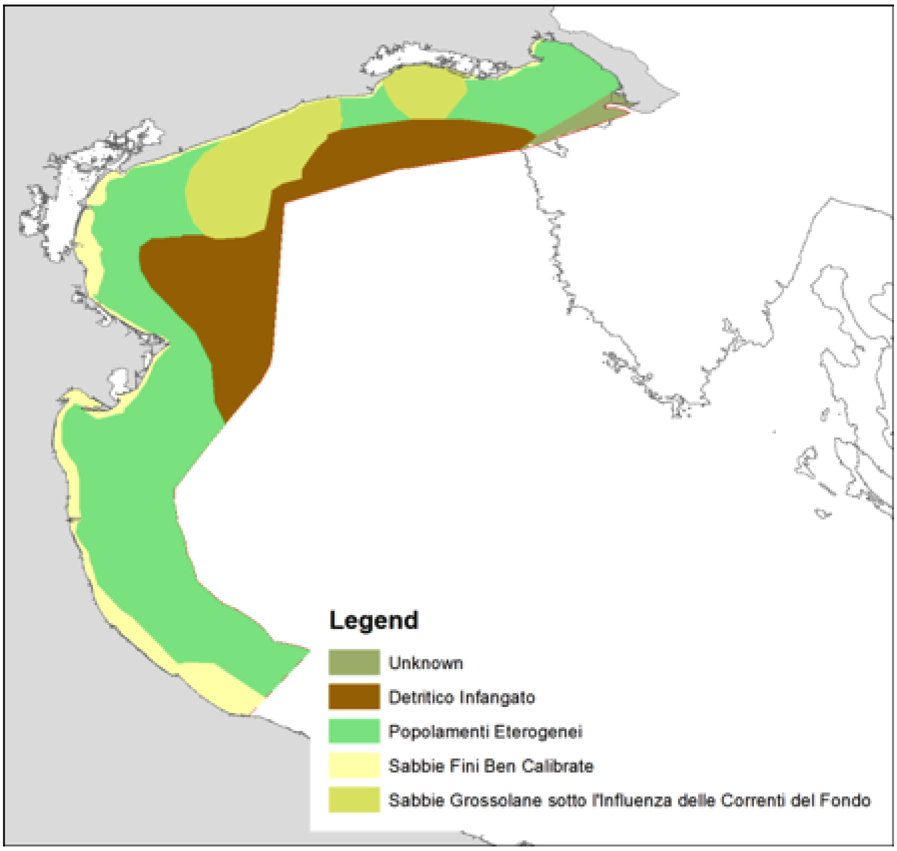


Figure 2.4.40 - Distribution of the main benthic coastal habitats in the region (source ISPRA 2012). Habitats are: detritico infangato = mud; popolamenti eterogenei = heterogeneous sedimentary habitats, sabbie fini ben calibrate = well sorted sand, sabbie grossolane sotto l’influenza delle correnti del fondo = coarse sand.

The North Adriatic Sea is a strategic area for marine vertebrate conservation, sheltering important seabird populations (Zotier et al. 1999, Baccetti et al. 2002). The area also includes important populations of endangered marine mammals, turtles and elasmobranchs (Delaugerre 1987, Groombridge 1990, Manoukian et al. 2001, Bearzi et al. 2004, Ferretti et al. 2013). Many of these species have been severely overfished and depleted: they now occur at low densities (Tab. 2.4.18), and their fragmented populations are facing significant anthropogenic threats.

Tab. 2.4.18 - Elasmobranchs in the Adriatic Sea (source Ferretti et al 2013).

Species	Tows	Individuals	First	Last	Drange	Length
1 *Heptranchias perlo* (sharpnose sevengill shark)	2	2	1948	1948	27–1000	138
2 *Leucoraja circularis* (sandy skate)	2	2	1948	1948	70–900	120
3 *Pteromylaeus bovinus* (bullray)	1	44	1948	1948	10–150	250
4 *Galeorhinus galeus* (tope shark)	15	18	1948	1957	2–450	186
5 *Squatina squatina* (angel shark)	11	16	1948	1958	0–150	180
6 *Dipturus batis* (common skate)	14	17	1948	1968	100–1000	242
7 *Raja radula* (rough skate)	8	8	1968	1994	40–450	70
8 *Rhinoptera marginata* (lusitanian cownose)	2	2	1994	1994	30–100	200*
9 *Dasyatis centroura* (roughtail stingray)	4	4	1957	1996	3–270	247
10 *Dalatias licha* (kitefin shark)	3	7	1995	1997	40–1800	181
11 *Raja polystigma* (speckled skate)	2	2	1999	2000	100–400	60
12 *Dipturus oxyrinchus* (longnosed skate)	30	60	1948	2001	0–900	150
13 *Torpedo nobiliana* (back torpedo)	1	1	2001	2001	2–800	180
14 *Oxynotus centrina* (angular roughshark)	17	48	1948	2003	60–660	150
15 *Torpedo torpedo* (common torpedo)	2	2	1996	2003	0–150	50
16 *Chimaera monstrosa* (rabbit fish)	11	71	1994	2004	200–1000	87
17 *Etmopterus spinax* (velvet belly)	11	57	1994	2004	70–2000	53
18 *Rostroraja alba* (white skate)	16	18	1948	2004	40–500	200
19 *Squalus blainville* (longnose spurdog)	79	348	1948	2004	14–400	110
20 *Dasyatis pastinaca* (common stingray)	45	94	1948	2005	60–200	150
21 *Galeus melastomus* (blackmouth shark)	41	1147	1948	2005	50–1000	68
22 *Leucoraja melitensis* (maltese skate)	1	1	2005	2005	60–800	50
23 *Mustelus asterias* (starry smooth-hound)	63	94	1948	2005	0–100	140
24 *Mustelus mustelus* (smooth-hound)	186	1302	1948	2005	0–350	162
25 *Myliobatis aquila* (common eagle ray)	133	539	1948	2005	0–200	150
26 *Raja asterias* (starry skate)	55	129	1948	2005	10–300	72
27 *Raja clavata* (thornback skate)	536	3612	1948	2005	0–700	107
28 *Raja miraletus* (brown skate)	327	1780	1948	2005	50–150	66
29 *Raja montagui* (spotted skate)	9	9	1948	2005	0–550	77
30 *Scyliorhinus canicula* (small-spotted catshark)	812	24401	1948	2005	0–400	76
31 *Scyliorhinus stellaris* (nursehound)	139	396	1948	2005	0–100	150
32 *Squalus acanthias* (spurdog)	425	3632	1948	2005	10–200	125
33 *Torpedo marmorata* (marbled torpedo)	68	92	1948	2005	20–350	82

Species detected in the Adriatic trawl surveys (1948–2005). Tows are the number of trawl tows that caught the species. Individuals refer to the cumulative number of specimens detected in all tows. First and Last are the years of the first and last catch, respectively. Drange (m) and Length (cm) are the depth distribution range and maximum length of the species reported in the literature (* is disc width).

Concerning marine mammals, nowadays the common bottlenose dolphin (*Tursiops truncatus*) is the only regular component of the northern Adriatic cetacean fauna (Fig. 2.4.41), while the short-beaked common dolphin (*Delphinus delphis*) is now very rare (Bearzi et al. 2004).
The Adriatic Sea is a feeding and wintering area of extreme importance for the loggerhead (*Caretta caretta*). It is known from the literature that adult and sub-adult animals go into the north-western Adriatic Sea, which plays an important role in the biological cycle of *Caretta caretta*, both in the summer and in the winter time (Fig. 2.4.42).
Concerning soft-bottom macrofaunal assemblages at shallow sites (<20 m depth), these are characterized by high abundances of *Ampelisca* spp., *Nucula nucleus*, *Corbula gibba*, and to a lesser extent, unidentified Paraonidae, *Mysella bidentata*, and *Lumbrineris* spp. (Abbiati et al unpublished data). Assemblages at deeper sites (>20 m depth) have more balanced species composition and are characterized by greater average abundances of *Sternapsis scutata*, unidentified Cirratulidae and *Polycirrus* cf. *haematodes* (Abbiati et al unpublished data). Sites to the north (which are more under

the influence of the Po river plume) tend to be characterized by higher average abundances of *Abra nitida*, *Abra albra*, *Ampelisca* spp., *Polycirrus* cf. *haematodes*, *Polydora flava*, unidentified Cirratulidae and unidentified Paraonidae compared to southern sites.
In the north Adriatic sea, human pressure on the coast has been historically intense (Lotze et al. 2006, Lotze et al. 2011), and environmental problems are varied and severe, including: erosion and land subsidence (both natural and human-induced); developments of urban, industrial and tourist infrastructures; transformation and loss of native habitats and assemblages; eutrophication and spread of exotic species. Due to the cyclonic circulation, the Po river discharge impacts mostly on the coast of the Emilia-Romagna region (Artegiani et al. 1997, Boldrin et al. 2005), where eutrophication problems were observed from the 1970s, with periods of anoxia in the bottom layers and serious impacts on the environment and fishery (Artioli et al. 2005 and references therein). Other direct sources of natural or anthropogenic disturbance to the sedimentary benthos in the region include extraction of offshore relict sand for beaches (Colosio et al. 2007), dumping of harbour-dredged material (Simonini et al. 2007), fish trawling (Pranovi et al. 1998, Pranovi et al. 2000), and hydraulic dredging (Morello et al. 2006).

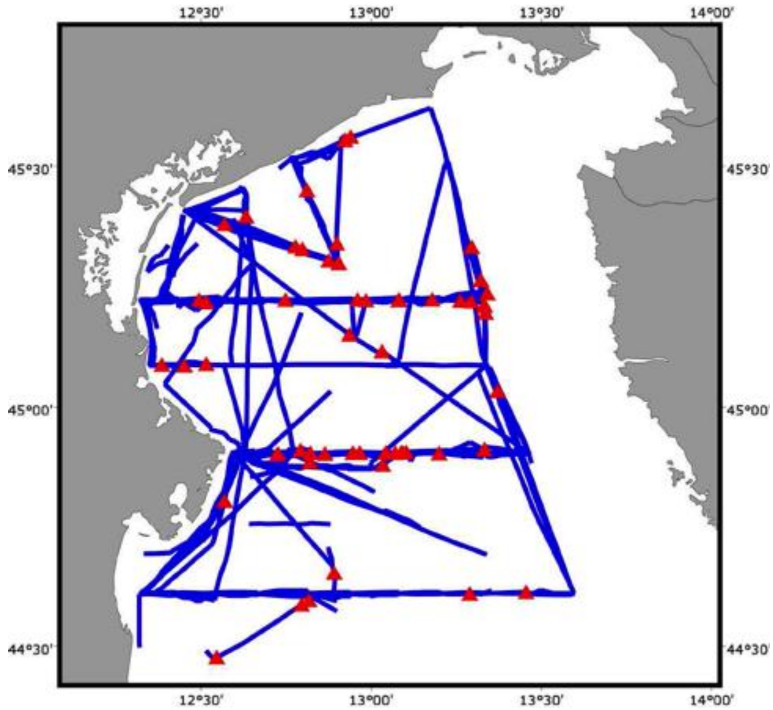


Figure 2.4.41 Routes travelled and sightings of *Tursiops truncates* during 2003-2006 (source Politi, http://www.arpa.veneto.it/arpav/chi-e-arpav/file-e-allegati/Bollettino_cetacei_ita.pdf)

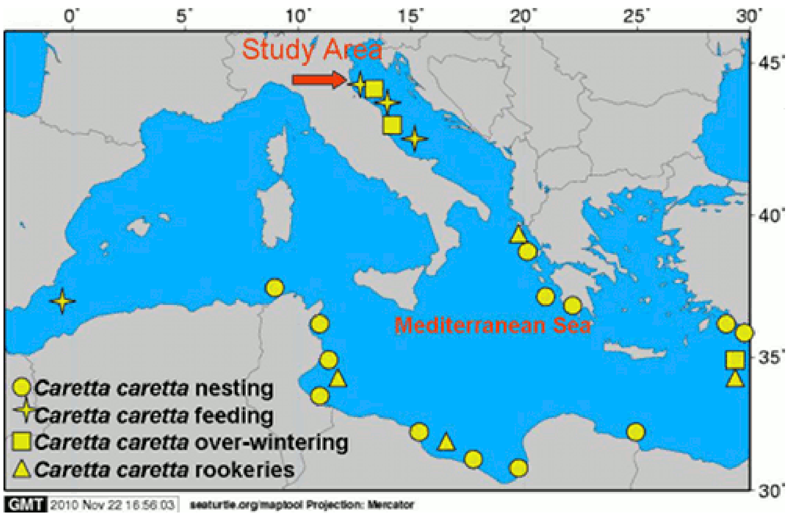


Figure 2.4.42 - Main distribution of loggerhead turtles in the Mediterranean Sea (source <http://www.seaturtle.org/maptool>)

2.4.6 **Social perception and constraints**

The development of this multi-use platform (MUP) has been discussed with relevant stakeholders in the area to research the views of the stakeholders. First, a session has been organised to which all relevant stakeholders were invited to introduce the MUP concept and the site. Later, all the stakeholders were asked to fill in a questionnaire. The results in this chapter are based on the discussion in the introduction session and the filled in questionnaires. In the beginning, a selection has been made of different groups of stakeholders that are important for successfully implementing a MUP: Energy companies/managers energy platform, Fishermen/aquaculture, Government, Private companies, NGO's. With help of this list, an overview had been made of all the relevant stakeholders. The following stakeholders were invited and attended the introduction session:

Luigi Rubino	SEABREATH - producer Wave Energy Converters
Carlo Buttazzoni	WEMPOWER - producer Wave Energy Converters
Giancarlo Alfiero	Clam Producer Cooperative in Chioggia
Sandro Carniel	National Research Centre (CNR) in Venice
Andrea Valentini	National Environmental Agency in Veneto
Mauro Marani	National Alternative Energy Agency in Veneto
Marina Aurighi	Regional Water Plan Office in Veneto
Giuseppe Spinoso	Harbour Office in Venice
Alessandra Vivona	Municipal Energy Agency in Venice
Daniele Scatto	Civil Engineers in Veneto
Oreste Venier	Neural Engineering SpA – Technical Consultant
Dario Bovo	Consorzio Venezia Ricerche - Technical Consultant
Sofia Faggian	eAmbiente - Environmental Consultant
Andrea Pavanini	Naval League in Venice - NGO
Luigi Lazzaro	Environmental League in Venice - NGO
Massimo Salviato	Hotel Keeper Association in Venice
Marco Cacciari	Citizen Committee for Venice Lagoon Preservation

The first group of stakeholders are the potential entrepreneurs to develop the research site into a multi-use platform. These are the energy companies, SEABREATH and WEMPOWER, and an aquaculture company, the Clam Producer Cooperative. Both energy companies might be interested in investing financial and human resources, if they are properly involved. The clam producers are the strongest economic and political representative of fish production in Venice. Second, different governmental agencies were invited to the introduction session. These parties could have a strong voice in the planning procedures. On national level, the national research centre (owner of the Acqua Alta platform), the national environmental agency and the national alternative energy agency were invited. Locally, the regional water plan office was invited. On municipal level, the harbour office and the municipal energy agency attended the introduction session. Furthermore, a few private companies attended the meeting: Civil engineers in Veneto, Neural Engeneering SpA, Consorzia Venezia Ricerch and eAmbiente. All these parties are consultants and could be consulted during the design process. Neural Engineering SpA might be interested in investing financial and human resources, if they are properly involved. Finally, two Non-Governmental Organisations, a tourist operator and the citizens committee were invited and attended the meeting.
All stakeholders attended the meeting, however from not all the questionnaires have been received. There has been no reaction from Civil Engineers in Veneto Region, Harbour Office in Venice and Consorzio Venezia Ricerche - Technical Consultant.

Social perception

Goals for participation

All stakeholders were asked about their goals for participating in this MUP. However, not all stakeholders are willing to participate in the MUP. The citizen committee has mostly social goals for participation. The activities that take place in the sea should be in favour of citizens. Both energy companies, the national alternative energy agency and the technical consultant have strong economic goals for participating in a MUP. Both energy companies designed a wave energy generating prototype which they would like to test on the site. The most important goals mentioned by these four stakeholders are: Explore new markets, More efficient use of energy, Improve companies image, Combining production and nature values.
The other stakeholders, focus strongly on the environmental goals as most important goals of the MUP. Among the goals considered most important for participation in MUP development are found: More efficient use of space , Reduce negative impacts on the ecosystem, Combining production and nature values, More efficient use of energy.
The project seems to be interesting as a socio-economic lab to integrate private and public institutions in order to use marine resources in a conscious and responsible way, in a long run perspective preserving the ecosystem.

Prerequisites for participation

Stakeholder participation is mentioned as a prerequisite by almost all stakeholders: a MUP design is a complex and multidisciplinary work, involving economic, scientific and technical issues in a long-run perspective. This implies that a cooperation between (direct and indirect/institutional) stakeholders is essential, in order to identify an harmonic strategy for the public welfare.
A well-known scientific and independent institution could favour these strategic choices. Stakeholders should be involved during the whole process.

Other prerequisites relating to stakeholder involvement and a participatory process that were mentioned often by the stakeholders are trust between stakeholders, clear roles and multidisciplinary cooperation.
Furthermore it is mentioned that the site location should not be fixed in advance. Since contrasting interests are involved and affected by location, stakeholders said that location should not be fixed in advance, but it should be something to bargain.
The energy companies and technical consultant mention economic prerequisites for participation. These are access to educational facilities to educate people with the skills needed for the site and financially attractive arrangements to execute the plans.
The application of the revised Simos' procedure, once normalised and averaged over stakeholders, produces the following relative weights: Weco = 27, Wsoc = 25, Wenv = 48. Similarly, the linear regression, once normalised and averaged over stakeholders, leads to the following relative weights: Weco = 31, Wsoc = 29, Wenv = 40. In other words, the environmental issues are crucial, with economic issues perceived to be more important than social issues. These results will be used in designing our MUP.

Social Constraints

Obstacles for participation

Some serious obstacles for participation are mentioned by interviewed stakeholders. *Site location and restrictions.* In the coming years, an off shore port will be built before the coast of Venice for Asian ships. This port is seen as an obstacle by the stakeholders. The off-shore port is located closely to the research site. Nonetheless, there are no relationships between CNR platform and the off-shore port. Until a specific location has been chosen for the wave energy converter, we must consider the potential development of the off-shore port in choosing the location for the wave energy converter. *Governmental regulations.* Energy companies are worried about the permits that are needed to conduct their activities. At the moment there are not sufficient permits are available to conduct the activity on the platform. *Financial issues*. The Clam Producer Cooperative is not interested in participating in this project. Main reason is that they are already involved in other project and do not have the human and financial resources available to invest in more projects. In the future, other parties could be asked to participate in this project/MUP. However, as mentioned before, the Clam Producers are the strongest economic and political representative of fish production in Venice. Other obstacles that are mentioned are uncertainty about the availability of personnel, additional costs that occur during the process and time investment.
Attention should be paid to direct and indirect environmental impacts: it is not clear how many trips will be done and how large the boats will be that will be used daily to feed and transport the fish, apart from other trips related to multiple uses. The pollution impact from feeding fish (once a week) should be taken into account as well. Additional information on potential conflicts with naturalistic areas, fishery activities or tourism activities is lacking, apart from the conservation of an interesting ecological area. New and different fishery activities could be detrimental to biodiversity as well as to the current fishery sector. Attention is needed for the potential conflicts around the site before they become an obstacle.

Conditions for the design

The conditions for design have not been discussed with the stakeholders during the introduction session and the questionnaire. The major issue raised by the stakeholders was the determination of the exact location of the MUP. The site location should not be fixed in advance.

Contrasting interests are involved and affected by the choice of the location, stakeholders mentioned that location should not be fixed in advance, see Tab. 2.4.18. It is something that could be taken into account during the design process.
Environmental impacts should be taken into account during the process. The majority of the stakeholders argue that a MUP should not cause any environmental impacts. The stakeholders mentioned that research on the environmental impacts is lacking at the moment.
Combination of wave energy with aquaculture seems difficult as the only aquaculture company that has been interviewed does not want to participate in a MUP due to a lack of personnel and financial resources. To successfully implement the MUP, another aquaculture company must be found. However, the clam producers are the strongest economic and political representative of fish production in the area.

Table 2.4.18. SOCIAL CONSTRAINTS

Fishery pay attention to water eutrophication from fish feeding; preserve today diving and favour future diving activities in 3.5 to 8 miles; consider future ship routes to Trieste; new and different fishery activities could be detrimental to bio-diversity as well as to the current fishery sector
Energy doubts about the selected site, in absence of additional information on potential conflicts: off-shore port, naturalistic areas, tourism activities

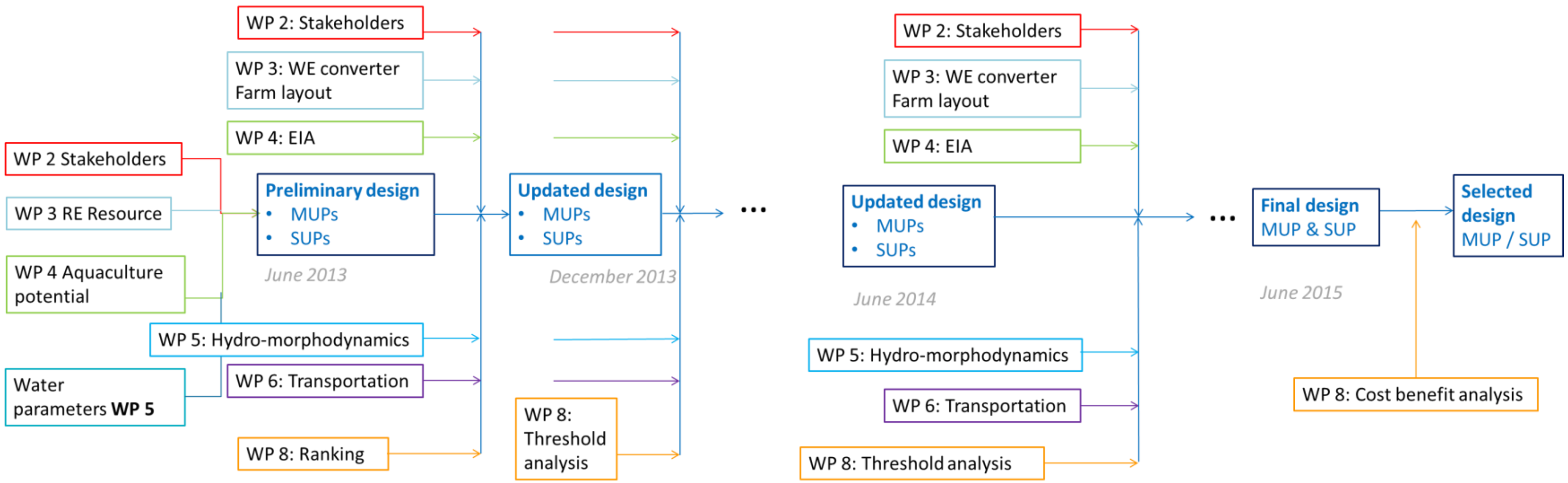
These insights will be used in designing our MUP.

3 Preliminary design

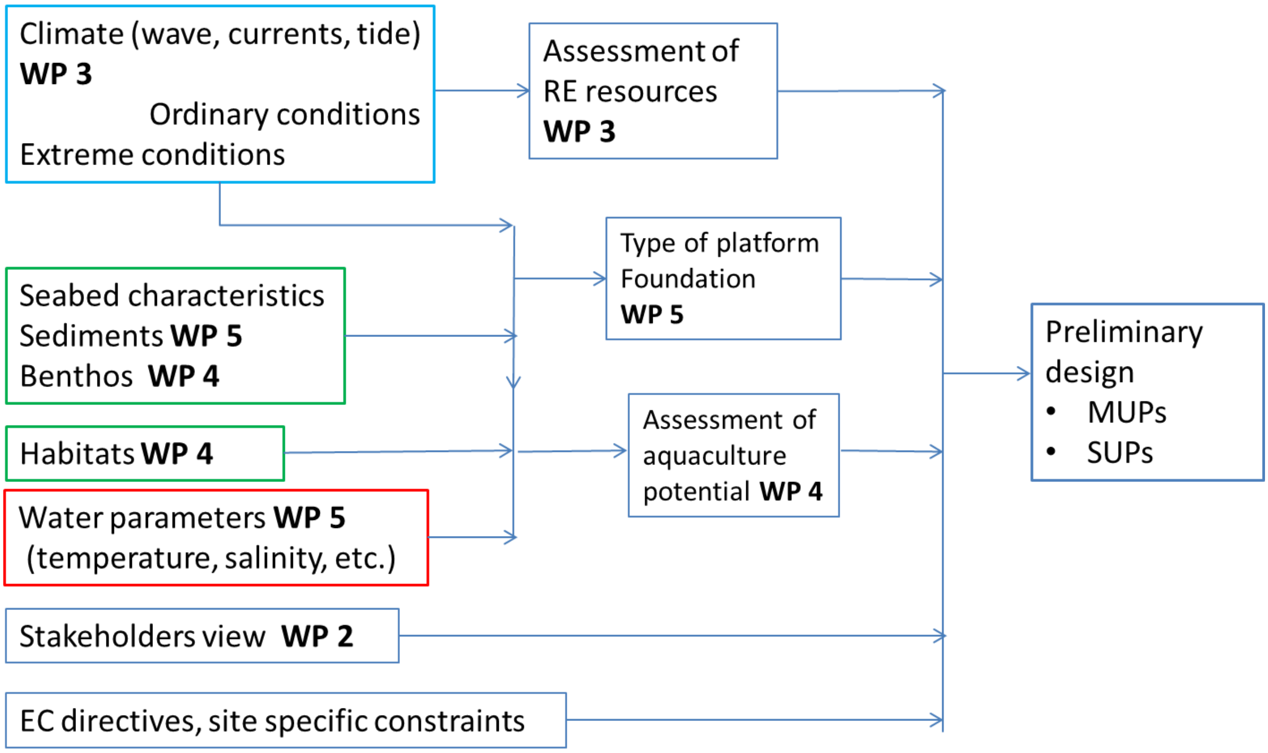
3.1 The procedure

A specific threshold analysis will be applied to alternative combinations of uses (i.e. wave, fish, wave and fish, wave and fish and wind) in order to identify the minimum IRR as dependent on (unknown) environmental benefits or costs. Indeed, a threshold analysis is a methodology which calculates the minimum value to be attached to (unknown) environmental benefits or costs in order to justify the choice of a particular option. In particular, some design options might be excluded because of an unsatisfactory IRR. Next, a specific Cost-Benefit Analysis will be applied to the most promising alternative combination of uses in order to measure its overall net benefit. Indeed, A CBA is a set of rules for the economic evaluation, with the aim of guiding (consciously or unconsciously) decisions between alternative potential interventions, in order to identify the projects that maximize the social welfare (i.e. the net social benefits = social benefits – social costs). In particular, the chosen design option might be rejected because of an unsatisfactory Net Present Value, due to its environmental impacts properly estimated in monetary terms.

3.1.1 Overall design procedure



3.1.2 Preliminary design - overview



3.1.3 Step 1- Feasibility assessment

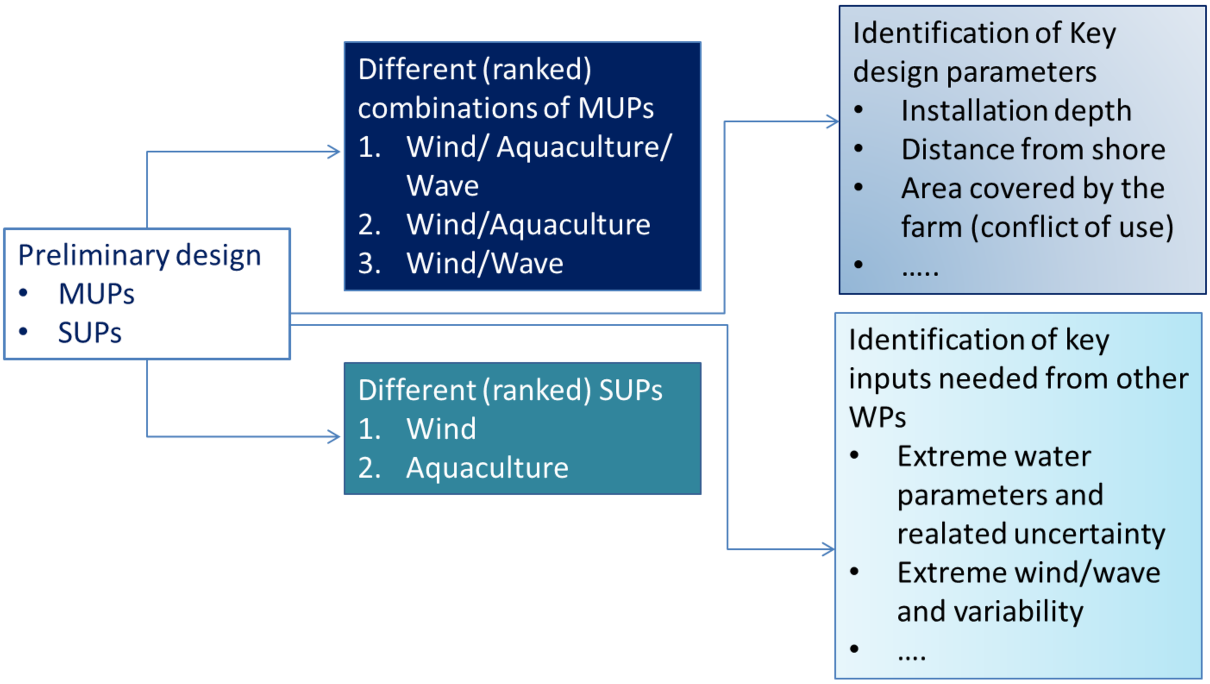
Criteria	Type of judgment
Renewable energy potential • **Wind** • **Wave** • **Tide**	Yes/no • Wind: >6m/s on average for off-shore plants, after ORECCA, 2011 • Wave • Tide: 2.5 m/s mean spring peak based on DECC, 2010
Aquaculture potential	Yes/no – if yes specification of • what (sea-weeds, fish farm, etc) • required minimum installation requirements that may affect (depth, energy, space, etc.)

3.1.4 Step 2 - Ranking

<table>
<tr><th>Criteria</th><th>Type of judgment</th></tr>
<tr><td>Environmental impact</td><td>Score: 1 (lowest)…5 (highest)
Use of marine space
Wind piles/devices dimension
Size of energy farm
Size of aquaculture farm
Foundation type
Materials
Creation of habitats for native species
Impacts on native habitats and species
Impact on the coast
Inclusion of exposed components/parts
Noise /Vibration
Aesthetic impact
Local energy storage/use
Maintenance
Transportation
Fouling
Material durability</td></tr>
<tr><td>Risk</td><td>Score: 1 (lowest)…5 (highest)
Structural failure:
Modular or single/ rigid structure
Geotechnical failure (liquefaction)
Moorings
Power failure
Power take off
Local energy storage/use
Pollution</td></tr>
<tr><td>Costs</td><td>Score: 1 (lowest)…5 (highest)
Installation depth
Materials
Moorings
Power extraction and storage
Power take off type
Local energy storage/use
Transportation</td></tr>
</table>

Judgment criteria, weights and threshold values to be defined after testing and validating the procedure within the expert focus groups of site teams.
The example application of the procedure has been carried out for the Mediterranean Sea.
Separate rankings have to be carried out for multi-purpose and single-purpose platforms.

3.1.5 **Step 3 Outcome**



3.2 Estuarine site, Baltic Sea

3.2.1 Single and multi-purpose design concept

The Kriegers Flak KF offshore wind farm is already scheduled to be in operation in 2020 (site location in Fig. 3.2.1). To this end, obvious additional activities and commercial use of platform is aquaculture of fish (rainbow trout and/or Atlantic salmon) and production of seaweed in specific *Furcellaria lumbricalis* that can be cultured at the low salinities characteristic for the KF area.

Suitability for energy conversion

A key design consideration in the wind turbine design will be the foundation. At Kriegers Flak with relatively modest wave conditions and depths up to about 25 m two concepts appear suitable: either a gravity based foundations or a jacket structure.

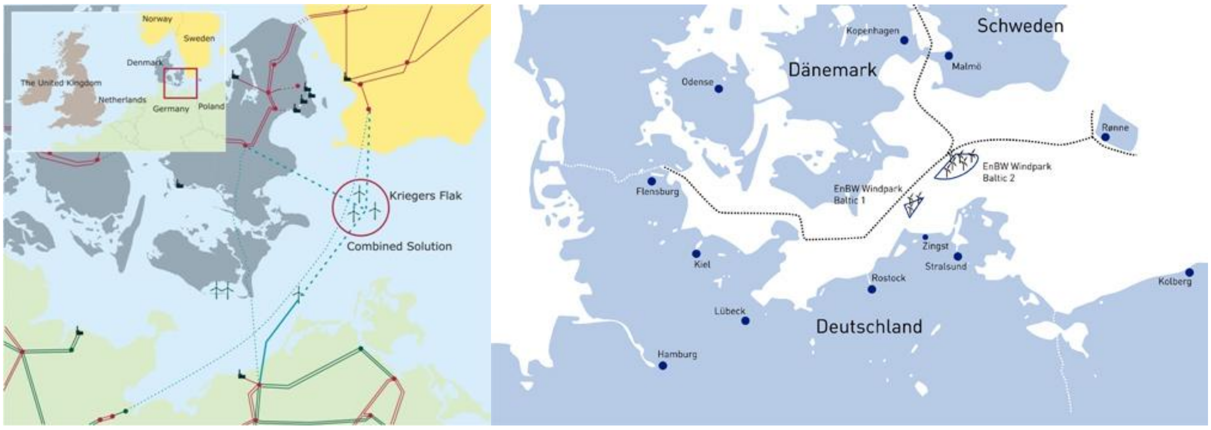


Fig. 3.2.1 – Maps: Kriegers Flack and placement of the decided German Wind farm Baltic 2 at Krigers Flack (power production from 2014)

Foundations for the coming wind farm at the Danish part of the Kriegers Flack has not yet been decided. This will be decided by the entity winning the concession of the site.
However the German project Baltic 2, also situated at Kriegers Flack already decided to use a combination of monopiles and jackets. 39 monopiles at depths from 23 - 35 m, and 41 jackets for depths of 35 meter and more.
The wind turbine foundations seem not of particular importance for the multi-purpose design of the Kriegers Flack. However if a accommodation platform for crew to handle assist in maintenance of the wind turbines should be established, this platform might serve as host for other purposes. Below is described facts about installation of the monopile and jacket structure (see Fig. 3.2.2).

The monopile tube rests in the soil – often with approximately the same length below the seabed as above – and goes up all the way above the waterline. On top, a transition piece provides the connection between support structure and the wind turbine tower.
The transition piece is also a tube (Fig. 3.2.3). It has a slightly larger diameter than the monopile and can thus be mounted over the monopile. On top of the transition piece a flange secures connection with the tower using nuts and bolts. The transition piece typically weighs from 150- to 250 and is around 25 meters high.

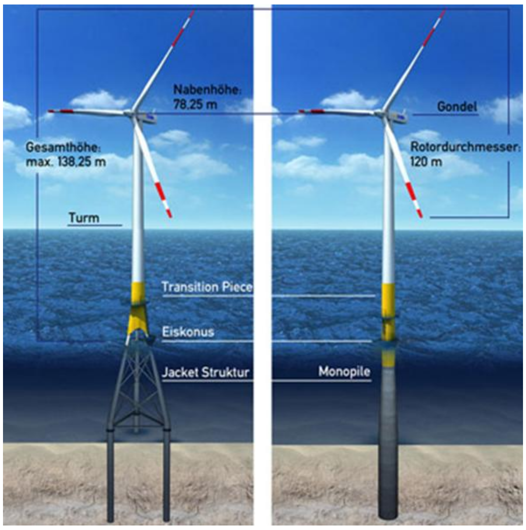


Fig. 3.2.2 - Tripod or monopile. Figures from Baltic 2 (http://www.4coffshore.com/windfarms/enbw-baltic-2-germany-de52.html)

The transition piece is necessary because of the method used to install the monopile into the sea bed. The structure is hammered into the soil using a hydraulic hammer – the same method used on land to pile foundation for buildings . The transition piece is also used to level the flange. The transition piece is connected to the monopile using cement or grout. A solid filling is needed to transfer all loads and forces from the wind turbine tower through the transition piece down to the support structure.

In general monopole have the following advantages:

- Simple construction
- Well documented method
- Cheap producution
- Cheap production

And disadvantages:

- Grouting crumbles over time
- Need for scour protection
- Large hydrodynamic loads

Figure 3.2.3 - Transition piece

The concept of jackets origins from the oil and gas industry (www.lorc.dk/offshore-wind/foundations), see Figure 3.2.4. Jackets have been used for supporting rigs at a depth of more than 100 meters.
A jacket is made up of three or four main legs, connected to each other by bracings. All elements are tubular unlike onshore lattice structures which are usually made from angular profiles.
Like the monopile, a jacket needs a transition piece to support the wind turbine tower. The transition piece also includes the working platform just below the wind turbine tower. But unlike the monopile concept, the transition piece on jackets does not have to level the construction. Levelling is done at the seabed. The transition piece of a jacket is mainly mounted onshore during fabrication of the complete structure.
At the seabed, the structure is often attached into the ground using piles, but gravitation bases or suction anchors/buckets are also possibilities. The foundation of a jacket with piles can be carried out as either post-piled or pre-piled.

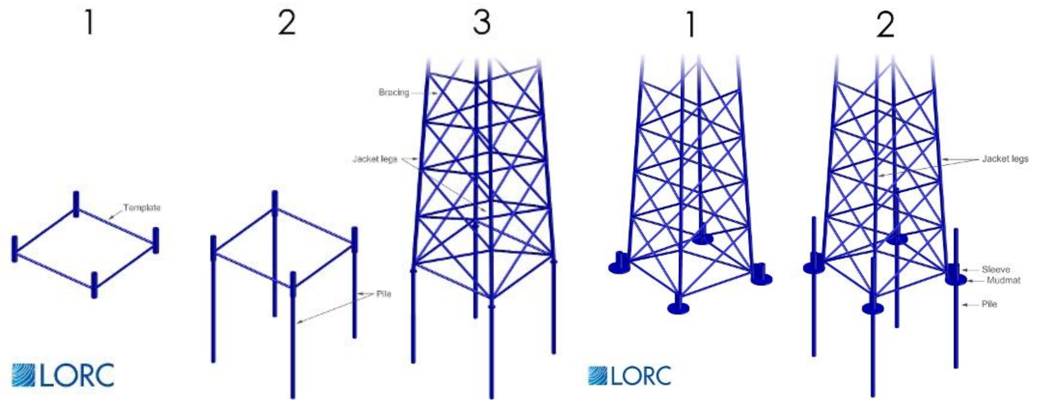


Figure 3.2.4 - Pre - piling and Post - piling of the jackets foundation
(from http://www.lorc.dk/offshore-wind/foundations)

Jackets demand preparation of the seabed. In most cases, a template is used to drive down the piles ahead of installation. The template is essential for driving the piles at an accurate distance from each other. Using post-piling makes the template unnecessary, but requires pile sleeves at each jackets.
Transporting the finished jackets to site is literally a big thing.
The transition piece is installed before transport to sea and then the tower and turbine in sequence.
In general jackets have the following advantages

- Good resistance to overturning
- Light and efficient construction

and disadvantages

- Many man-hours of welding
- Complicated transportation to site.

Suitability for aquaculture development

The Kriegers Flak is highly suitable for production of rainbow trout and Atlantic salmon. If production is planned to take place on the shallow plain (18-22 m) sturdy 120-140 m off-shore cages should be used, e.g. anchored in groups of 3 nets. If calculation of wave stress shows that the load on cages (and fish) is too large, submersible cages could be used, but this would require a depth of at least 40 m and probably would make establishment of wind generators less cost-efficient, if wind and aquaculture should be combined. If it is decided that a combination of wind energy, fish aquaculture and seaweed production are feasible calculation of load on individual systems should consider the “shading” effects of the three systems combined.

Use of the platform

The multi-use platform at Kriegers Flak will be used for combined energy production from wind turbines and aquaculture of salmonids, possibly also with aquafarming of seaweed.

3.2.2 **Preliminary conceptual platform design and planning**

Structural support and design

Two different preliminary designs of wind farms have been suggested, one consisting of 200 3-MW-turbines and another based on 8 MW turbines (Fig. 3.2.5). In either case there is ample of “empty” space between turbines or in the non-occupied area between the two groups of turbines to establish a large aquaculture facility combining salmonid production and seaweed production arranged in a manner to dampen waves.

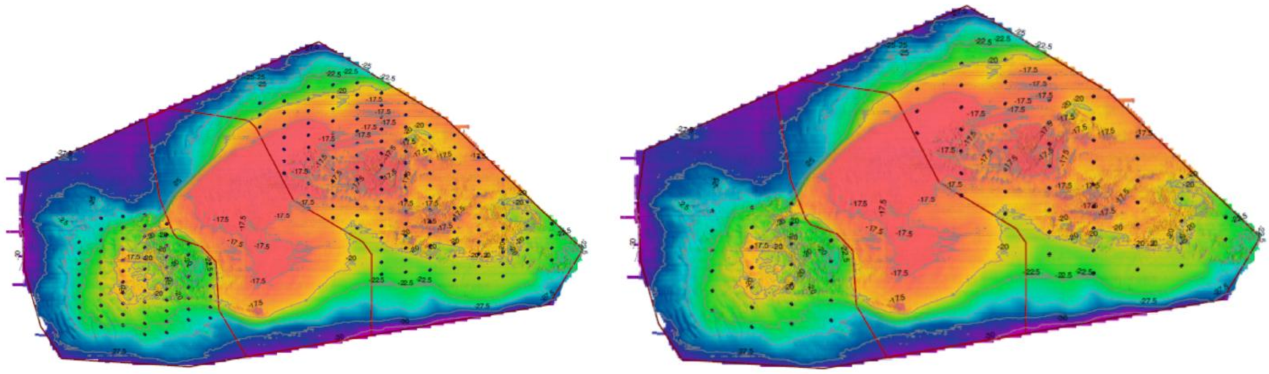


Figure 3.2.5 Two preliminary layouts of wind farm to be established at Kriegers Flak; left: based on 3 MW turbines; right: based on 8 MW turbines. (from “Dokument nr. 37007/13, sag 12/497”)

Off-shore energy storage and/or transmission systems

Kriegers Flak is located 30 km off shore in the center of the Baltic, thus grid connections to shore are a key part of the project. In addition to the onshore transport of energy, the central location also opens the possibility for establishing a connection between the grids in DK and DE via Kriegers Flak. The grids in DK and DE are nor synchronized thus it may be beneficial to use HVDC lines, connected to onshore substations with conversion to the local grids. This may require local DC conversion using an off shore substation at Kriegers Flak. Offshore energy storage may be relevant to the extent that the aquaculture farming is supplied directly from the wind turbine production. However the consumption of the farms may not be significant, thus it may be a more optimal solution to use only one net.

Transport and logistical analyses

Transportation and installation of offshore wind turbines are related to various specific factors. Factors that must be identified to improve the installation performance according to different special conditions.

Parameters like wind and sea always limit and narrow the time window for a safe installation. The time window is so important and must be calculated accurately to avoid risky situations that can occur on the way and at the site.

The distance from the shore to site or from the port to site increases the travel time. In this case this parameter will be at least 30 km, but that might also increase to several hundred kilometers in worst case, depending on the nearest load out harbour. This factor creates the need of higher service speeds and larger cargo capacity for the installation vessels.

Different options for installing the wind turbines offshore exist. Different installation vessels, different turbine models etc. , and in this case we do not know what type of turbines that will be installed. It might be 3,6 MW turbines, but if the installation first will be made in 2020 6 MW or higher might be the preferred turbine size. Offshore turbine installations require lifting of heavy pieces and placing them at certain heights. In order to safely install these heavy turbine components, most installation vessels rise on their jack up legs to create a stable working platform. These installation vessels are mainly specified in two groups: “Self-propelled installation vessels”, and “Jack up barges” (Fig. 3.2.6).

The self-propelled units that for the most recent builds, specially designed according to offshore wind industry’s demands. These self-propelled installation vessels have jack up legs and cranes with high lifting capacities. Their service speeds are also normally higher than the other installation units.

Figure 3.2.6 - Jack-up barge.

Jack-Up barges are floating units that are capable of elevating themselves above the water on their jack up legs at the construction site. They are not self-propelled units and must be towed to the construction site by tug boats. The service speed of the barges is dependent on the tug's power. Most of them are originally designed for general construction and drilling purposes or some origins from the oil/gas industry but still they are used in offshore wind industry commonly as well. .
As mentioned above the sizes of the wind turbines are increasing as the rated power of the turbines go up. This enlargement in the size of the machines adds other challenges to the offshore installations. While the weight creates a demand for bigger lifting capacities, the increasing hub height requires taller booms for the on-board cranes. The increased volume of the turbine components occupies more space on the installation vessel which decreases the number of turbines that can be placed on the deck at a time.

Offshore wind farm sites mostly are selected especially for the combination of shallow water and their good wind potentials. This aspect limit crane operations in terms of available time window for lifting the components safely due . Since choosing a less windy site is not an option for solving this problem, different installation concepts were developed to reduce the duration of offshore works in order to fit it in narrow time windows. These concepts are based on carrying components already assembled (pre-assembled) at the port, see Fig. 3.2.7.

Figure 3.2.7 - Pre-assembled turbine parts in the harbor.

A wind turbine (without the foundation and transition piece) consists of 6 main parts. These are tower, nacelle, hub and three blades. Considering that the towers are usually carried in two pieces, the number of components becomes seven which in return increase the number of onshore assembly alternatives again. However there are five methods mainly being applied in the offshore turbine installation industry.
These methods can be summarized as follows:

- Nacelle, hub and two of the blades are assembled at the port. The tower is carried in two pieces and the third blade is also placed separately on the same boat. Therefore one turbine is transported in **four pieces** to the site and requires four offshore lifts at the construction site.

- Nacelle, hub and two of the blades are assembled at the port. Tower is also assembled to be carried in one piece and the third blade is placed separately on the same boat. Therefore one turbine is transported in **three pieces** to the site and requires **three offshore lifts** at the construction site.
- Hub and three blades are assembled at the port shaping the complete rotor. Tower (in two pieces) and nacelle are placed separately on the same boat. Therefore one turbine is transported to the site in **four pieces** and requires **four offshore lifts** at the construction site.
- The tower is assembled at the port and carried in one piece. The hub and nacelle is assembled at the port as well. The blades are left separately and placed in the “blade stacker”. Therefore one turbine is transported in **five pieces** to the site and requires **five offshore lifts** at the construction site.
- The hub and the nacelle are assembled at the port. The tower is carried in two pieces and the blades are placed in the “blade stacker” separately. Therefore one turbine is transported in **six pieces** to the site and requires **six offshore lifts** at the construction site.

All the concepts mentioned above have either positive or negative effect on the installation performance. Increasing the amount of pre-assembled pieces on the deck decreases the offshore installation time, but in fact the increased volume of the assembled structures must be considered as it can lead to a less efficient way of using the available deck space of the vessel. Carrying assembled pieces on the boat requires good sea conditions. This is also another fact that makes the project flow more dependent on the sea conditions.

Installation, operation, maintenance and decommissioning

Access

Gaining access to an off-shore wind-farm for routine servicing and emergency maintenance is difficult, or even impossible in harsh weather conditions due to wave heights, wind speeds and poor visibility. The traditional and obvious method for transporting personnel and equipment is by boat, which is limited to wave heights below 2 meter (dependent on site- and vessel characteristics).
Since the beginning of offshore wind farm development, suggested methods for gaining safe access includes helicopters and crew accommodation platforms. This was used for the first time at the Horns Rev 1 (2003) wind farm (helicopters), and off-shore platforms for the crew at Horns Rev 2 (2009). An alternative to the accommodation platform is to use a hotel ship during the yearly service period.

For the present discussion, only the principle advantages and disadvantages of boat or helicopter access will be considered.

Boat Access advantages:

- well proven method of inshore transportation
- relatively cheap equipment expenditure

and disadvantages:

- impractical for wave heights greater than 2 meter (dependent on vessel)
- transfer of personnel and equipment
- difficult in rough conditions.

Helicopter Access advantages:

- sea state is not a major issue
- quick transfer of personnel and equipment from land to turbines

and disadvantages:

- cost of equipment and qualified operating staff
- turbine must be shut down and locked prior to boarding, and flying is restricted to good visibility and wind conditions
- expensive and cumbersome (landing platforms needed on each turbine)

Which methodology that will be used at Kriegers Flack is still uncertain. For - only - boat access speaks the relatively limited wave height for the area, and the establishment of a crew platform is also very uncertain.

Operation and maintenance.

Today the global installed capacity of wind turbines has reached almost 200 GW spread across the world. Onshore wind power is now considered the most mature renewable technology and operators have obtained significant experience in operation and maintenance (O&M) of wind farms. The most common approach for large onshore wind farms is a combination of scheduled maintenance, typically one to two visits per year and reactive maintenance, restoring components after failure. This approach has been deemed to be cost effective for operators and has allowed onshore availabilities of over 97% to be achieved..

In the last decade offshore wind energy has experienced exponential growth to a worldwide installed capacity of over 3GW focused in Northern European waters. This expansion has coincided with the arrival of larger, multi MW machines suited to sites with higher mean wind speeds and has been driven by the decrease in available onshore sites and planning issues. This is particularly true in the UK where applications for large onshore wind farms have met increasing planning difficulty and public resistance due to their visual impact. In addition, offshore projects currently at the scoping or development stage in Europe total exceed 100GW in capacity.

Uncertainty exists around the costs of O&M with estimates ranging from 20 – 33% of overall project cost seen over the lifetime of the project (Valpy, 2010).

Decomissioning

The procedures described in the following will be used for the Lincs off-shore wind-farm, but the procedures might also be suitable for Kriegers Flack.

The wind farm at Kriegers Flack is expected to have a lifetime of at least 20 years. When decommissioning the following might be taken into account.

Turbines

The scale of offshore wind turbines mean a large amount of material will need disposal upon decommissioning of the structure. Opportunities to re-use the generating equipment should will be maximised whenever possible. The first phase of decommissioning is to prepare the site which will typically include;

- de-energise and isolate required electrical control and power cables from national grid;
- removal of all loose items from the structure;
- containment and removal of liquids such as lube oils/transformer liquids etc.
- installation/certification of lifting points; and
- hot bolting key bolts to aid unbolting process.

Once the preparation has been completed, it is expected that the remaining structure will be removed by crane in reverse process of their installation as follows:

A. Removal of the three individual turbine blades
B. Disconnection/removal of nacelle and turbine.
C. Cut tower at transition piece and remove to jack-up vessel.
D. Cut transition piece connection to foundation.
E. Remove all components onshore to an appropriate handling facility and disassemble all parts to sizes suitable for reuse, recycling or disposal as follows:
   - removal of all hazardous substances and fluids from the turbines (e.g. oil reservoirs and hazardous substances) to be disposed of in accordance with relevant regulations at the time of decommissioning;
   - all steel components sold for scrap to be recycled. This forms the bulk of the structures and substructures;
   - the fibreglass turbine blades will be disposed of in accordance with relevant regulations at the time of decommissioning.
F. Cut turbine interconnecting cables adjacent to the substructures. Cables to be left in situ.

Proposed Decommissioning of Foundations and Transition Pieces

If monopiles are used the resulting construction is of a size that will not be easily removed entirely from the seabed once driven down to the design penetration depth. Therefore the monopiles will be cut off below the seabed.

This will happen through removal by cutting at an appropriate depth such that any part of the pile remaining in the ground is likely to be covered by seabed sediment.

The general target for cutting is 1m below the seabed (still depending of actual request from authorities) , though this is likely to be varied due to individual localised factors such as ground condition at each site. When assessing the possibility of cutting below the seabed it is important to consider the need to overcome frictional forces acting on the pile.

The removal of the pile would take the place in the following manner:

A. The seabed within the monopole is excavated to approximately 1m below required cutting depth. Excavated sand and silt, through which the pile was originally driven, will be disposed of on the seabed adjacent to the pile. Such material is native to the area and can therefore be considered uncontaminated.
B. Remotely operated high pressure water/grit cutting tool is set up within monopole at appropriate cutting depth.
C. Monopile/transition piece are rigged up onto the decommissioning vessel crane.
D. Monopile is internally circumferentially cut at appropriate depth.
E. Upper cut section of monopile (including transition piece), once cut free, is lifted out of water and placed onto jack up vessel deck or floating barge.
F. Batch of recovered monopole sections are transported to shore for recycling.

The material around the monopole may be consolidated and (depending on depth of cut) require significant crane capacity to remove. In the worst case, it may be necessary to use vibrating hammers as part of removal process to assist in separating the material from the pile.

- Wire Cutting - This involves cutting through the monopile with steel cutting wire. The cut would be carried out from the outside of the pile, requiring external excavation to an

appropriate cutting depth. The requirement to first remove scour protection from around the base of pile makes this option less attractive; and
- Explosives - Explosive cutting is also a well-known method but it is not expected to be first choice.

Proposed Decommissioning of Offshore Substation

The decommissioning of the transformer platforms will follow similar method as described for the turbines and turbine foundations. The first phase of decommissioning is to prepare the site which will typically include

- de-energise and isolate required electrical control and power cables from national grid;
- removal of collector and export (and associated fibre optics) cables back to cable deck, or seabed;
- removal of all unsecured loose items from the structure;
- containment and/or removal of liquids such as lube oils/transformer oils etc.;
- installation/certification of lifting points; and
- cutting welded stab-in connections between topside and jacket.

The complete “topside” structure will be removed. It will then be taken by suitable vessel to an onshore facility where the equipment and structure will be dismantled and the constituent parts processed for reuse, recycling and or disposal.

It is proposed that the four legged jacket, including leg piles, are removed by cutting the crown shims and jacket-pile welded connection off. The piles will then be pulled from the jacket or the jacket lifted from the piles and piles cut at 1m below seabed.

Proposed Decommissioning of Marine Export and Inter-Array Cables

The intention would be to only remove those offshore cables, sections of offshore cables or cable ends which are uncovered at the time of decommissioning. This will be determined by survey prior to decommissioning of the site. This intention is based on the aim of minimising environmental disturbance to the site.

Cables in this category will be removed by lifting cable ends onto the cable retrieval vessel and the cables will be spooled back onto a drum.

Prior to decommissioning, a contingency plan should be developed for resolving the potential issue of cables becoming exposed post decommissioning.

Scour Protection

Should scour protection be required at some stage during the project life-cycle, at the decommissioning stage, this scour protection material will not be removed from the area. By their nature these materials would be difficult to recover and, in any case, should provide useful marine habitat as artificial reefs. Any scour protection that is moved in order to access turbine bases will be left in situ.

Proposed Waste Management Solutions

Reuse should be considered, followed by recycling, incineration with energy recovery and, lastly, disposal. In any event, waste management should be carried out in accordance with all relevant legislation at the time of decommissioning.

3.2.3 **Risks**

The combined wind-turbine and aquaculture will pose an increased risks due to complex navigation. The fish cages are floating structures that may break the moorings during severe conditions and potentially damage neighboring turbines or cages.

3.2.4 **Environmental impact assessment**

Comprising both fixed and floating structures, the environmental impact assessment (EIA) will address both impacts on the seabed during installation and during operations. The EIA of the turbines will follow modern standard procedures for EIA, addressing impacts both during installation, such as noise, sediment spills and other spills and possible impacts on habitats. During operation EIA will address effects of scour around the structures, impacts on birds and wildlife among other things. The aquaculture part will have some direct physical effects from anchoring and mooring lines, but the impact from the production on water quality and habitats may be the most significant. For both activities impacts from the decommissioning will have to be addressed.

Impacts include the effects of noise on marine mammals and fish, disturbance and loss of habitats, bird collisions and visual intrusion. Offshore structures can also interfere with other uses of the sea – causing hazards to shipping and the servicing of the offshore industry, and displacing fishing activities and recreational boating. The grid connections will need separate investigations along the cable routes, addressing impacts on conservation issues, noise or impacts on habitats.

3.2.5 **Socio-economic impact**

The socio-economic impacts of the multiuse platforms combining wind turbines, floating fish cages and seaweed farms will be designed such that the impacts on the environment are acceptable and such that they will have a positive financial impact. To ensure this a process is started in WP 2 to get commitment from all relevant stakeholders and the financial constraints and possibilities will be an integral part of the ongoing design. The final socio-economic impact will be evaluated during WP 8 which will compare the direct costs and benefits of the MUP, both for investments, operation and management and removal of the MUP. Finally monetary value of the external effects will be included in an overall socio-economic cost benefit analysis of the MUP.

3.3 Active morphology site, North Sea and Wadden Sea

3.3.1 Single and multi-purpose design concept

Suitability for energy conversion

The potential for wave energy convertors in the North Sea is in the order of 10~15kW/m^2 (see Mermaid deliverable D3.1). Following the yield status of the wave energy convertors available to date, this function in stand-alone mode appears for an economically point of view not feasible. However, making use of the available infrastructure of an offshore wind farm, and taking into account that the wave energy at the lee side of the wave energy convertors will be minimized the suitability of wave energy convertors in the North Sea becomes interesting. At least its feasibility should be further studied.

Minimizing the wave energy propagating towards the offshore wind farm results in less extreme as well as fatigue loadings at the wind turbines and infrastructure of other possible functionalities. This implies that the wave energy convertors will possibly be installed outside the offshore wind farm at the location facing the dominant wave direction (waves coming from Northwest).

Suitability for aquaculture development

Based on the assessed hydro-morphological conditions and water characteristics, the suitability of the site for aquaculture development is examined and the key design parameters (installation depth, required space, mooring lines, etc) are identified. Aquaculture development is intended to include: fish farming, mariculture, seaweed farming.

Considerations for mussel aquaculture

In Dutch aquaculture, mussel production is the dominant activity with highest revenues and profits. Mussel culture is concentrated in Zeeland and the Wadden area. Around 50 companies are actively involved, producing around 50 million kg of mussels annually during the last years. In 2011, turnover of the sector was 56M€, employing 170 FTE. EBIT was ca. 19M€ (STECF, 2012). Market expansion is difficult, although there is a reported market demand of 50.000 tons.

The production of mussels (in tonnes) has declined quite a lot since 1996. In 1996 92,000 tons of mussels were produced. In 2009 the production was only 46,000 tons, a decline of almost 50%. One of the reasons is a shortage of spat due to environmental restrictions on the catch of wild spat and a natural shortage of spat in the areas where catches are still allowed. The dominant method for collection of mussel spat is by bottom trawling but given the ecological impact of and social resistance of this method it is now difficult to get permits.

In recent years, the mussel sector has experimented with alternative collection methods. So called “MZI”, using long lines that float in the Wadden Sea, have proven successful. Experiences with on-sea mussel spat collection in the Wadden Sea have shown the technical and economic feasibility (Kamermans et al, 2008).

To increase mussel spat collection, the sector has to look for ways to collect mussel spat and produce consumption mussels outside the Wadden Sea. Steenbergen et al (2005) evaluated the opportunities for mussel cultivation in open sea.The results was a “Mussel Opportunity Map” that describes in which areas of the North Sea, mussel cultivation is possible (see Figure 3.3.1).

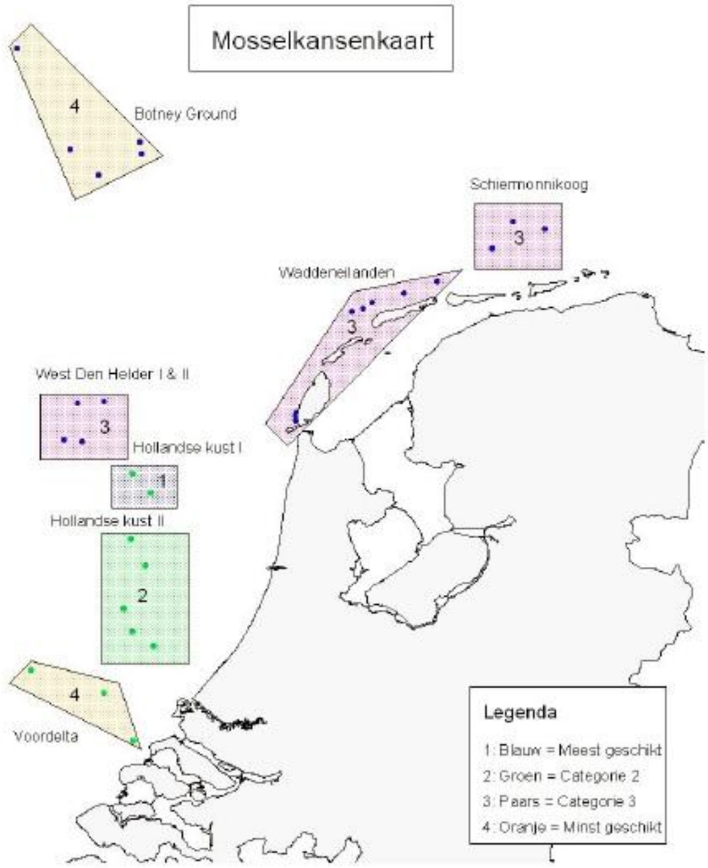


Figure 3.3.1: Opportunities for mussel cultivation in the North Sea
(1= most suitable, 4= least suitable)

The results of this study show that mussel cultivation in the North Sea is possible. Note that the Mermaid study site is not the most favorable location as there is less mussel spat available in the area. However, the quality of the mussels produced is higher than in other areas (Steenbergen et al, 2005).

Considerations for fish aquaculture

As is seen in the other MERMAID sites, fish aquaculture is another option in designing multi-use systems. However, As to date, no fish culture activities take place In the Dutch North Sea. Feasibility studies for the North Sea have shown that conditions in the North Sea are not suitable for aquaculture of the most important commercial species. Throughout the year, temperature differences hinder the growth of target species such as salmon. In summer, sea water temperature is too high. To overcome this, the fish cages should be submersible. However, insufficient water depth in the North Sea makes this impossible (Reijs et al, 2008; van den Burg et al, 2013).

Reijs et al (2008) indicate that in the Dutch North Sea the potential is highest for seasonal culture where fast growers are fattened. Based on these criteria only the Bluefin Tuna and Cod are promising species for aquaculture in the North Sea. Cod aquaculture is only possible when systems are available that can be situated at lower depths during the warm summer months, as water temperature in higher water levels rise too high. Consequently, depth is a restriction to location choice for this type of culture. Since estimated required water depth is a minimum of 35-40 meters, cod aquaculture is only possible is a limited area of the North Sea. Production of Bluefin Tuna is another option as it can be realized in 1 summer season.

Considerations for seaweed aquaculture

Seaweed cultivation systems can have a significant impact on hydrodynamics, morphology, ecology and other user functions of coastal areas. A floating installation can affect local currents and waves, and thus lead to erosion and / or sedimentation of the seabed or shore. By creating hard substrate and greatly increasing the adhesion surface, the entire seaweed installation delivers shelter, attachment sites and, indirectly, food for various organisms, which could lead to an increase in biodiversity and bio-productivity. The nutrient uptake by seaweed could counteract eutrophication. On the other hand, the installation could limit nutrient availability for other users (mussel cultures) and the surrounding ecosystem.

For the selection of an optimal site for seaweed culture, a balance must be found between nutrient availability, turbidity, and flow and wave forces. Large wave-impacts further offshore would require a very resilient offshore structure. Closer to shore, the installation would have to deal with alternating flow directions. Flexibility of installation is therefore important; a balance must be sought between the flexibility and rigidity of an installation.

To maximize the productivity of the seaweed, a minimum flow needs to be assured to provide nutrients and CO_2 (depending on the type of seaweed). Existing spatial planning of the North Sea limits the availability of areas where seaweed culture is permissible. With small sized pilot seaweed systems like the Hortimare pilot in the North Sea, relatively few effects are expected on the existing currents and waves. Around the small mooring of the culture system, little scour is expected, especially when the location is subject to changes in flow directions. However, in shallow locations, erosion may occur underneath the seaweed system. In order to minimize this, a deeper location should be selected, and the system should be designed to create as little obstruction of the water column as possible, by optimizing the shape, flexibility and orientation of the installation.

In nutrient limited areas, a seaweed system should not be placed close to other aquaculture installations (other than those designed as part of the IMTA), in order to avoid negative influence. Seaweed culture is most effective in nutrient-rich areas with relatively low turbidity, and a constant flow to provide the seaweed with a constant supply of nutrients and CO_2. In areas where seaweed cultivation is possible, potential (indirect) interactions of seaweed cultivation with the environment should be taken into account (impacts on other aquaculture facilities, collision risks for shipping and recreation, risks of damage to infrastructure - wind turbines, dikes - by loose parts of the seaweed installation, etc.). It is then possible to select areas where adverse effects on other users and the environment are minimal, and that are also optimal for culturing seaweed.

In the North Sea, potential locations for seaweed culture are limited by other functions (navigation, oil rigs, etc.), but conditions are generally promising: high nutrient levels (some areas in the North Sea are even eutrophied), acceptable levels of turbidity (further offshore) and currents.

3.3.2 Use of the platform

The primary use of the platform is wind energy.
Four additional uses for the platform are selected:

- Wave energy generators
- Fish farming
- Mussel farming
- Seaweed cultivation

The wave generators and the mussel farming will be positioned outside the mooring area of the wind turbines. The fish farms and seaweed cultures will be placed in between the wind turbines. The spatial planning of the wind turbines has a major influence on the available area for fish and seaweed. The seaweed cultures need to be located close and downstream of the fish farms to catch nutrients excreted by the fish.

3.3.3 Preliminary conceptual platform design and planning

The wind turbines are positioned on a 1000m spaced grid. Sufficient area around the wind turbines is reserved for maintenance access. The wave generators are located in front of the wind turbine grid facing the wave direction with maximum wave energy. The mussel farms are located along the sides of the wind turbine grid in narrow, long fields perpendicular to the tidal movement. The seaweed cultures occupy most of the available area inside the wind turbine grid. The fish farms are located in small patches within the seaweed cultures. The size of the fish farms is small in order to maintain a balance between fish excrements and seaweed nutrient.

3.3.4 Structural support and design

The wind turbines and wave generators are mounted on a foundation.
The fish farms and mussel and seaweed cultivation are floating, kept in place by anchors. The anchor points arepilar type with fixed positions in the seabed.

3.3.5 Offshore energy storage and/or transmission systems

The fish farms need a small amount of electricity for areation and feeding of the fish.

3.3.6 Transport and logistical analyses

The wind turbines and wave generators require 200m free area for major maintenance access, ie installation and turbine overhaul.
The floating mussel, fish and seaweed systems are maintained with small ships and the maintenance access is part of the design. Harvesting ships make use of the larger reserved areas for maintenance of the turbines.

3.3.7 Risks

The seagriculture(mussel, fish, seaweed) systems are floating systems with a 10 year lifetime. The material may foul and the buoyancy of the buoys will show any unacceptable fouling weight. The seagriculture system may show rupture of individual ropes which diminishes the economical value, but the material will be kept in place by the redundancy of multiple ropes. The ships that sail near to the seagriculture system must be protected against entanglement of ropes in the propeller.

3.3.8 **Environmental impact assessment**

Impacts arise throughout the life cycle of offshore structures, including: site selection, construction, operation, decommissioning and removal. Impacts include the effects of noise on marine mammals and fish, disturbance and loss of habitats, bird collisions and visual intrusion. Offshore structures can also interfere with other uses of the sea – causing hazards to shipping and the servicing of the offshore industry, and displacing fishing activities and recreational boating. There may also be conflict with marine conservation objectives (OSPAR QSR 2010).

Knowledge of the wider effects of offshore structures on environmental quality is limited and mainly based on data from monitoring at specific sites, similar activities, government sponsored research and development, and predictions from EIAs. As with other construction on the seabed, wind farms may also have positive impacts, for example, by restricting other human activities, such as fishing. The degree and extent of these benefits is still being established (OSPAR QSR 2010).

Impacts on the environment due to development of offshore wind power plants and power transmission cables, are not only caused by direct emissions to air, soil and water. Effects on competing maritime uses and marine environment must also be taken into account when assessing environmental impacts. There are also environmental impacts caused by for instance visual impairments of the seabed topography, noise and smell. These factors can affect benthic flora and fauna, birds, marine mammals, fish and other, and are considered as serious environmental impacts in development of offshore wind farms and placement of submarine cables. Placement of windmill foundations, towers, rotors and transformer stations require space both on seabed, in the air and in water. This can lead to habitat loss for benthos, birds, marine mammals and fish, which can be very difficult and critical for some species.

Constructing an offshore wind farm will also create a change in the seabed's landscape as foundations and submarine cables require interference with, and preparation of the seabed. Depending on what type of foundation is used, this will include digging in the seabed and use of artificial hard substrates. As a result, this can harm seabed integrity and significantly affect benthic communities or species. (Köller, J. Köppel, et al. 2006).

It should be mentioned that the impacts on for instance benthic fauna and flora will be greater for fixed windmills than for floating windmills, as floating structures interfere considerably less with the seabed (Birkeland, 2011). For extended knowledge of the consequences wind farms have on flora and fauna, see the status report of the environmental monitoring program of Horns Rev offshore wind farm (Vattenfall A/S 2005) or the book *Offshore Wind Energy. Research on Environmental Impacts* (Köller, W. Peters, et al. 2006).

3.3.9 Socio-economic impact

In order to come up with feasible designs it is essential that the design team and the economists of WP8 work together. In order to come up with a feasible design, the designs must not only be technically feasible, but also financially attractive and have a positive socio-economic impact, which means that external costs and benefits should also be positive. Otherwise the financial profitability would have significant negative impacts on either society in general or the environment. WP8 can assist the design team in selecting financially attractive MUP that will also have a positive (or at least not negative) contribution for society and the environment.

In order to be able to perform this evaluation WP8 will need data on direct costs and benefits of the MUP, both for investments, operation and management and removal of the MUP. Furthermore, information is needed on possible effects (positive and/or negative) of the MUP on the environment and society in general. After selection of promising designs of the MUP, WP8 will assess the monetary value of the external effects in order to perform the overall socio-economic cost benefit analysis of the MUP.

3.4 Open deep water site, Atlantic Ocean

Based on the information summarized in Deliverable 3.1, the Cantabrian Offshore Site main strength are:

- Wave energy
- Wind energy

The site is an open ocean location with a significant water depth, because of that this particular site has not got enough current energy to be harvested.
In terms of aquaculture, the site is exposed to energetic seas and swells and located in a cold water area. Therefore, the site will not be suitable for aquaculture purposes.

3.4.1 Single and multi-purpose design concept

Suitability for wave energy conversion

The Cantabrian Offshore Site is a good location in terms of wave energy resource. The mean wave energy resource on 50 m deep is 20 kW/m. With respect the seasonal variations, in winter the average wave flux is around 36 kW/m and in contrast, in summer the average wave flux is around 7 kW/m.

The site is suitable for wave energy conversion also due to the water depth. Near the coast there are sites with limited depth, where bottom fixed WECs can be deployed. Nevertheless, the site is optimum for offshore wave energy technologies. Depth is quite high within a short distance from the shoreline, and then offshore deployment is easy with short cable laying. In terms of deployment wave energy devices can be easily deployed due to the proximity of the Santander harbor.

Regarding the multi-energy platform purpose a combined wave-wind use is possible in this location although wind energy resource is not very high in this area.

Suitability for wind energy conversion

This site is suitable for wind energy deployment. Average velocity (m/s) exceeds the minimum requirements for wind energy development (v>6 m/s). As we can see in the figure the wind velocity through the time exceeds the minimum installation requirements for wind energy mills. However, the site is not optimum for this purpose.

In terms of depth, the bathymetry of the area is quite steep and then, for the selection of the wind technology, semisubmersibles are the most recommended one. TLP are not recommended due to the seabed characteristics and monopile because of the water depth. Then semisubmersible can be efficient in this area.

In terms of combining energy technologies, a combination of wind and wave energy technologies could be positive. In the next figure the wind energy speed is represented for the last 60 year, taken from Seawind HR Database.

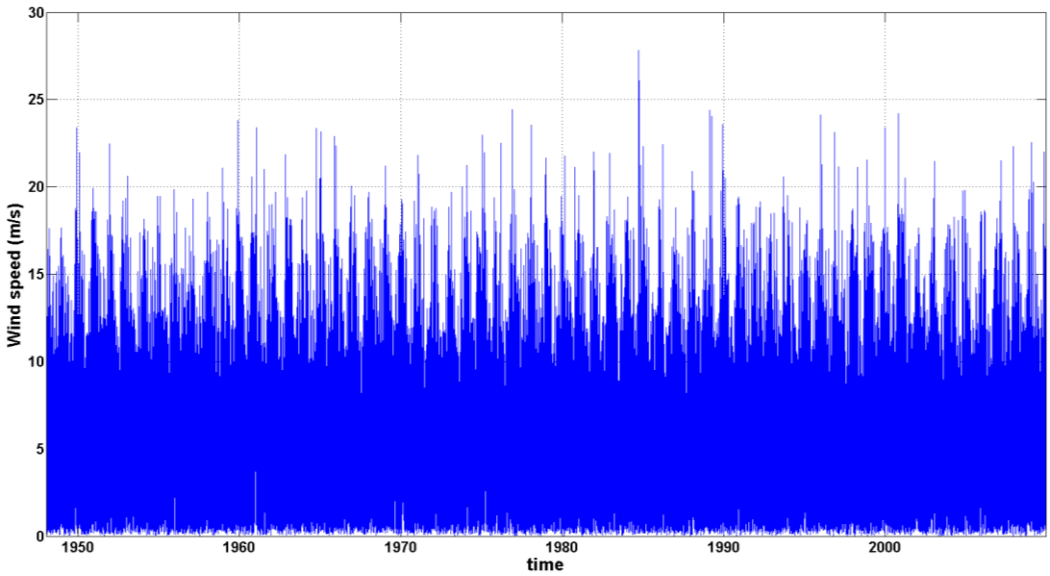


Figure 3.4.1 - Wind velocity at COS

Suitability for currents energy conversion

This location is not suitable for current energy conversion due to the limited current power available in the area. Although the tidal range is big (nearly 4-5 m), the bathymetry of the area does not provoke big currents in the area. Normally it is assumed that velocities of more than 4 m/s are needed in order to become a site for tidal development and in this case currents do not reach this value. Also in terms of depth, limited depth is necessary for current development. In this test site, the bathymetry is quite steep and then tidal development is quite impossible due to this fact.

Suitability for aquaculture development

In terms of aquaculture development some variables are investigated in order to determine its viability:

- Water temperature: In this test area water temperature is behind the required limit for aquaculture development. As we can see in the figure water temperature ranges from 10ºC to 20ºC. Then, especially in winter, water temperature is quite cold and the aquaculture is not recommended (see Figure 3.4.2).
- Water depth: the bathymetry of this area is quite steep and the range from 50 m to 200 m deep is found in a very small area. Then, this area is not recommended due to the limitations in terms of depth (see Figure 2.3.2).
- Wave height: as specified before wave height in this area sometimes reach very high values. Aquaculture is recommended for calm waters and then due to the severity of the met-ocean conditions, aquaculture is not viable in this area.

Therefore, none of the studied variables has a positive impact on the aquaculture development, and then aquaculture use is not recommended for multipurpose platforms.

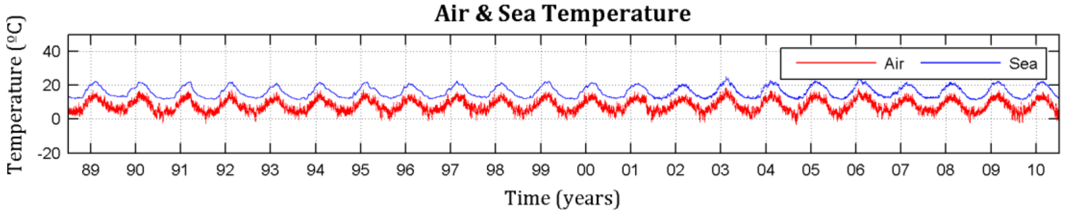


Figure 3.4.2 - Air and water temperaturefor the last 25 years

Use of the platform

Based on the considerations drawn above regarding the characteristics of the test site , a combined wave-wind technology is selected due to the recommendation of avoiding aquaculture and current energy in this area. Then, in terms of combining wind and wave technologies there are three different possibilities:

Combined wind-wave technologies at the test site with emphasis on wave technology

In this case, the test site is planned to host wave and wind technologies separately but without prioritizing wave energy or wind energy. The proposed scenario would content an array of 5 MW wave energy converters and wind turbines of 5 MW (large units). The following figure 3.4.3 represents an initial sketch o a possible the array. In this case the wave converters have been placed in front of the wind energy converter units in order to protect them from wave action.

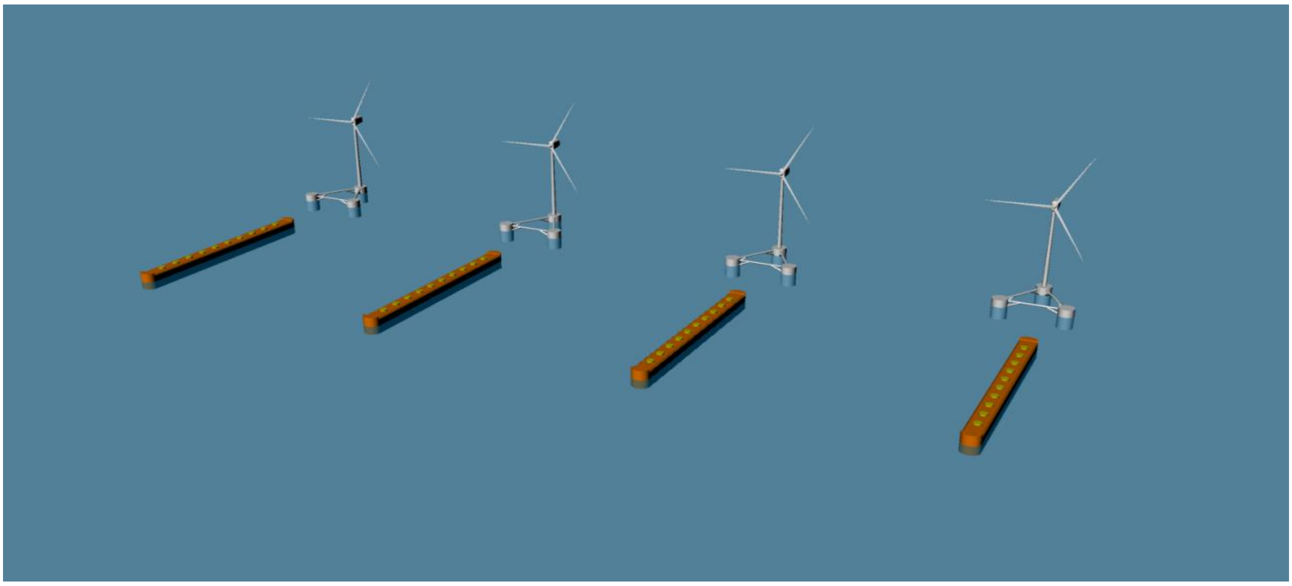


Figure 3.4.3: Combined wave-wind energy with emphasis both sources of energy

Combined wind-wave technologies at the test site with emphasis on wind technology

In this case, the test site is planned to host wave and wind technologies separately but prioritizing wind energy. The proposed scenario would content an array of 750 kW wave energy converters and wind turbines of 5 MW. In the following figure 3.4.4 a possible array setup is represented. As well as, the previous scheme, wave energy converters have been placed in front of the win energy converters in order to reduce wave action over the wind energy converter.

Figure 3.4.4 - Combined wave-wind energy with emphasis on wind energy

Wind-wave combined multipurpose platform design

In this case a multipurpose wind-wave energy platform is proposed. An initial scheme includes over a semisubmersible a wave energy converter based on point absorbers located on each leg of the platform, see Figure 3.4.5. These point absorbers are based on floaters that will move up and down (heave motion) and then they will extract wave energy from this heave motion.

3.4.2 Preliminary platform design and planning

According to Chozas et al (2012) the combination of wave and wind technologies reduce costs comparing it from the isolated energy point of view. The technical advantages are less fluctuating (less-peaks in the production) and more continuous (reduces periods of zero output and smooth changes) power output; increase predictability and reduces reserve capacity needed. Also, nowadays wind is difficult to predict, however, waves are much easier to predict so then a combined system increase predictability of the whole electrical output.

Comparing the above options, taking into account Chozas et al (2012) the election of one option depends on the site characteristics and the available resource at the test site. In this case, there is available a significative wave energy resource and a moderate wind energy resource, therefore the first option is recommended.

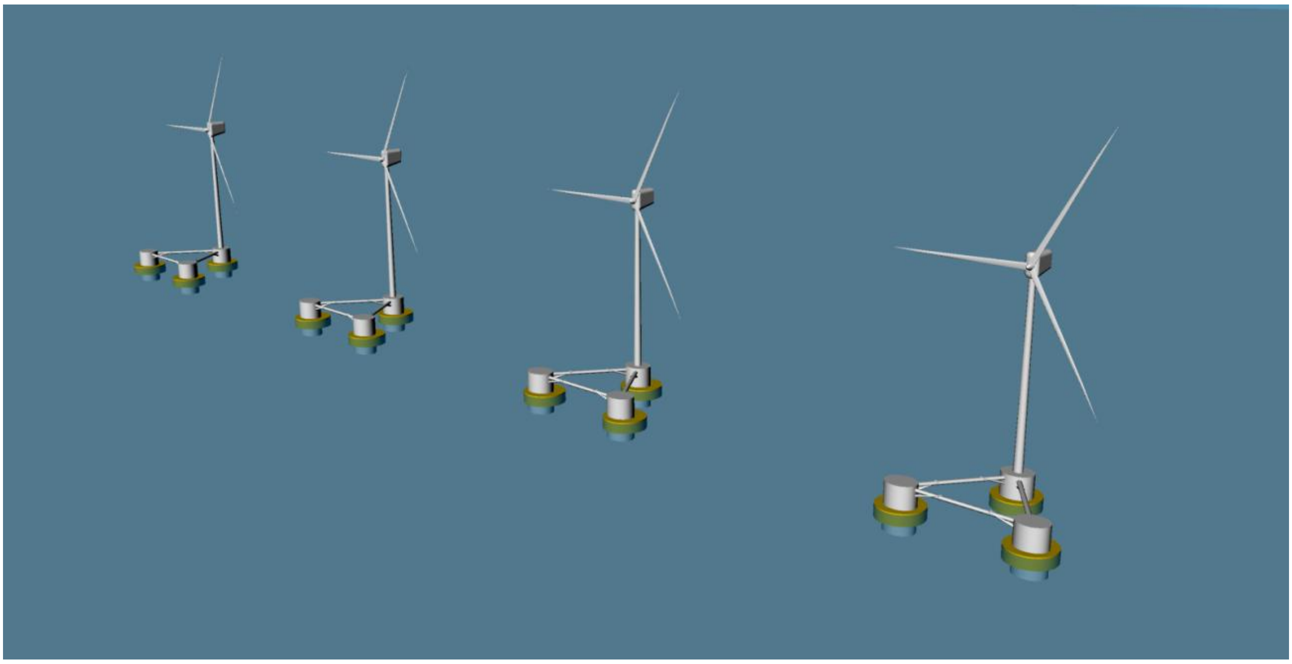


Figure 3.4.5 - Wind-wave combined multipurpose platform

Structural support and design

In the previous section an analysis of the combining energy option for the test site was made. The election was made taking into account the available resource in the area, and then a combined wind-wave energy site with emphasis on wave energy was chosen.

A farm composed by wave energy converters and wind turbines is proposed. The WEC selected for the farm will be a 5MW prototype composed by an array of floating OWC. There will be 10 chambers with turbines of 500 kW each per unit. The system is anchored thanks to conventional mooring lines and it will be oriented to NW, main direction in terms of wave energy flux. The wind energy converter will be based on a semisubmersible type floater; on top of it a 5WM wind turbine will be considered.

The initial design of both structures will be based on conventional materials (steel) in order to reduce design uncertainties.

Off-shore energy storage and/or transmission systems

The cheapest way to evacuate the energy is transforming it to AC current and rise voltage to reduce transportation losses. Then, in order to accomplish this task is necessary to use a power inverter, which corrects the output voltage regulating power and standardizing frequency. This task must be performed before transport in order to reduce transportation losses.

After this power inversion the signal can be corrected using a 13kV commercial transformer with a nominal power of 20 MW. It will carry the electrical current generated by the farm to the substation located onshore.

The onshore connection use a tripolar submarine cable on the seabed, taking into account that there are no risk of damage from fishing gear, anchors, etc... The union between the evacuation submarine cable and underground cable is done in a cavity located onshore. The cavity location should ensure adequate security and accessibility and it will be located also above the flood area.

Then the cable will be buried inside an underground PVC pipe to the depth required in the current law in order to minimize environmental impact.

The onshore cable must be connected to the existing distribution network by an electric substation. It should adequate its capacity to the electrical distribution characteristics of the island and have the necessary medium voltage equipment and a transformer in order to rise the voltage to the 66kV, for further transport.

Finally, the substation must have a low voltage system consisting of cooling, transformer regulation circuits and collector cells and the installation of a UPS (Uninterrupted Power System). This element is essential in order to feed elements that sometimes remain without electricity and are necessary for control and monitoring of the wave farm, the electricity network and lighting circuits.

In the Fig. 3.4.6 the electric transport process is shown for a point absorber farm, but this example could illustrate the process for a multipurpose site too.

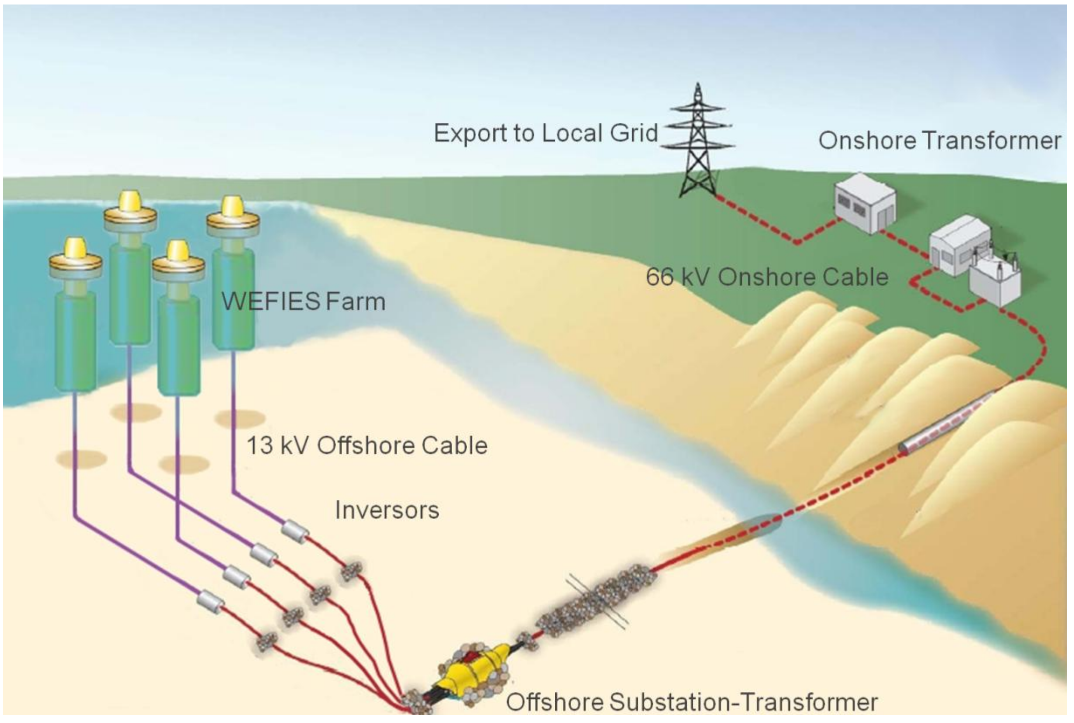


Figure 3.4.6: Schema of the electrical output from a wave energy farm

Transport and logistical analyses

The Cantabrian Offshore Site is located few kilometres north from the port of Santander. It is located 25km far from the quay line. Therefore, the site has a direct connection to a large facility. In terms of facilities available at the city, the following list summarizes the most important ones; most of them are highlighted in Figure 3.4.7.

- Transport facilities:
    - Santander airport: national and international flights
    - Train line with direct connection with: Bilbao, Madrid, Gijón and many other industrialized areas.
    - Motorway: easy road transport to South, West and East
- Industrial facilities
    - Shipyard and mills available on the region
    - Wind turbine manufacturers available at less than 100km (Gamesa).
    - Cable manufacturers available close to the city (Prysmian).
    - Other players of the supply chain available.

Based on the available facilities the need of space at the port as well as then need of quay line is not a problem nowadays; mainly because there is a lack of activity on the port due to the crisis.

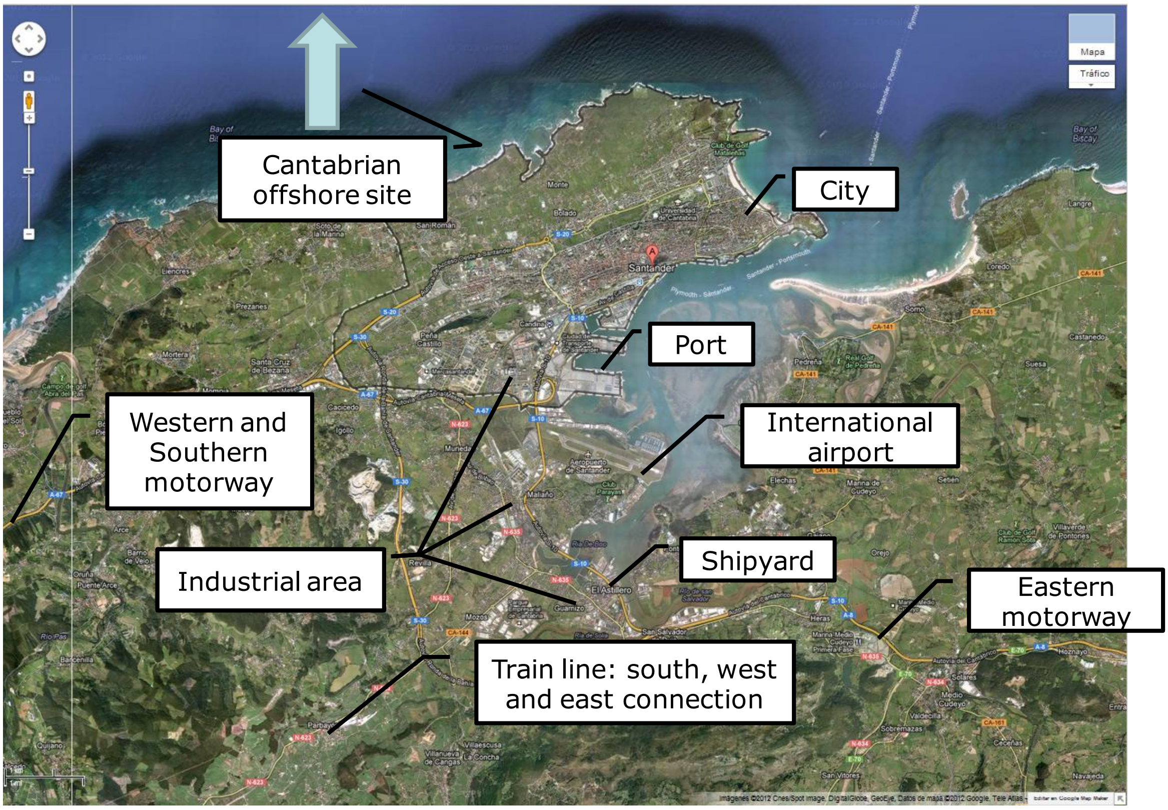


Figure 3.4.7- Cantabrian Offshore Site closest facilities

A long Mermaid project, logistics and transport needs and strategies will be addressed considering available facilities close to the site.

Installation, operation, maintenance and decommissioning

The concepts proposed are floating concepts and both of them are designed to be fully mounted at the quay. Therefore, only tug boats are needed to install and decommission each unit. Operation and maintenance can be addressed with conventional boats, since the proposed structures can be managed easily.
Finally, along the Mermaid project and in combination with the logistics and transport analysis, the needs and strategy for installation, O&M and decommissioning will be addressed.

3.4.3 Risks

The design considered up to this time it will be based on conventional structures (semi-submersible and ship-shaped WEC) as well as conventional materials. Mainly because of reduction of the uncertainties and risks involved on these kind of projects. Nevertheless, there will be a set of intrinsic risk not addressed nowadays by the level of development of the industry:

- Structural risks: There will be risks associated with the structural design. These kinds of risk are the same than the ones observed on similar applications: onshore wind and the oil&gas.
    - Fatigue of mooring lines, semisubmersible, tower and turbine
    - Corrosion of main structure materials
    - Station keeping system overloading
- Installation risks: failure of anchoring point, no sediment transport and pollution risk have been identified
- Structure-Environment interaction:
    - Thanks to previous experiences a significative bio-fouling may appear
    - Fish aggregated effect will be expected
    - Other environmental interaction.

3.4.4 Environmental impact assessment

The proposed concept is based on a floating technology. Therefore, the seabed will be only affected by the anchors and, up to some extent, by the mooring lines. Both impacts can be catalogued as low environmental impacts.

Moreover, recent experiences with floating structures in that area (Idermar project experience) has been a significant benefit identified. Thanks to the shelter given by the floating structure, around it the ictiofauna identifies that area like a safety area and an aggregate fish effect arise (see figure Figure 3.4.8).

However, the site is close to the shore line (5-20 km), therefore visual impact may be critical. Since this impact have been identified like one of the most important one by the Cantabrian community. Wind energy generating should be implemented as far as possible from the shoreline.

In terms of noise influence and birds impacts, specific studies must be carried out in order to identify the critical points.

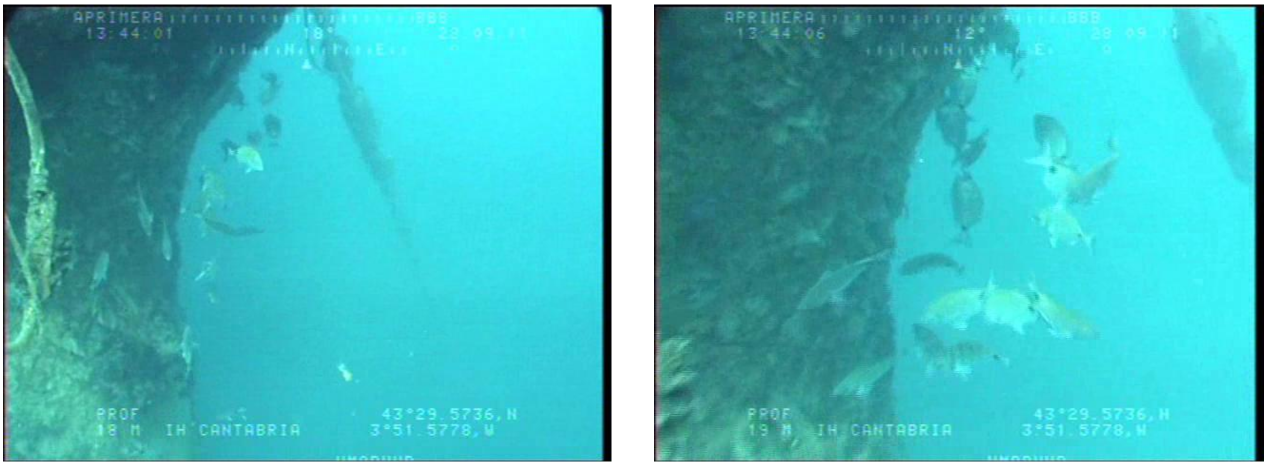


Figure 3.4.8 Aggregated fish effect at Idermar Meteo I floating met mast

3.4.5 Socio-economic impact

Based on the proposed concepts and energy converters integration a socio-economic impact analysis will be addressed. A long Mermaid project the following information will be generated:

- Levelized cost of energy
    - TIR
    - VAN
    - Finacial costs
    - etc.
- Environmental impacts of the MUP farm
    - Environmental costs
- Social impacts:
    - Social perception
    - Works generated
    - Local and regional economical synergies

Thanks to them, a socio-economic assessment of MUPs on an Atlantic Open site will be addressed.

3.5 Deep sheltered site, Mediterranean Sea

3.5.1 Single and multi-purpose design concept

Suitability for energy conversion

Wind Energy

Two options have been considered, large wind, referring to a multi megawatt, utility scale offshore wind farm built with the precise aim of being connected to mainland in order to sell electricity, and small wind (so called mini wind) with the main aim of supplying local offshore loads.

For both options, productivity estimation, namely annual energy production, has been carried out. The expected annual energy production of a wind turbine can be calculated by multiplying the wind distribution at the site, typically approximated to a Weibull distribution, times the wind turbine power curve. Per each wind class, the occurrence [hours per year] is multiplied by the expected power [MW] to be produced in the specific wind class. The simple calculation provides the annual energy production [MWh/y], which is the basis to build the business plan for onshore or offshore installation.
Due to the fact that overall annual energy production is dependent on how many turbines are installed, the concept of equivalent hours or capacity factor are of common use. The numbers respectively refer to the number of hours per year the turbine would work if always working at rated power (while instead, of course, the uppermost of the time is working below this point) while the capacity factor is actually the ratio of equivalent hours to 8760 hours per year. Both of those numbers, either expressed in hours or in percentage, provide an information of how many MWh per MW installed one should expect to produce.

The results of the analyses are resumed in table 3.5.1. Per each MW installed, large wind would produce 0.96 GWh/y, while small wind would produce 0.74 GWh/year. The main conclusion is that there is no margin for wind energy alone to be deployed at the site for energy production and sale. No detailed modeling is necessary to conclude that the lack of resource would strongly affect the business plan of any wind installation, due to the fact that the simplified calculations carried out so far are quite optimistic as wake effects, cable losses and machine unavailability would only lower the capacity factor.

Table 3.5.1 Synthesis of annual estimated power production for large and small wind installations.

	Large Wind	Small Wind
Hub height [m]	100	25
Mean wind speed [m/s]	4.54	4.06
Capacity Factor	11%	9%
Equivalent Hours [h/y]	960	745
Reference turbine	Vestas V112 3.3 MW	Bergey EXCEL10

A) Large Wind
According to the Italian wind atlas [http://atlanteeolico.rse-web.it/viewer.htm], the area is characterized by a mean wind speed ranging between 4 and 5 m/s at a height of 100 m above sea

level and ranging between 3 and 4 m/s at 25 m. According to this, Mermaid deliverable D5_1 dealing with Metocean Conditions estimated a mean wind speed at 100 m equal to 4.54 m/s.
The available resource appears to be quite limited, as Orecca FP7 project established a threshold value of at least 6 m/s at hub height for offshore wind energy to be potentially developed at a site.

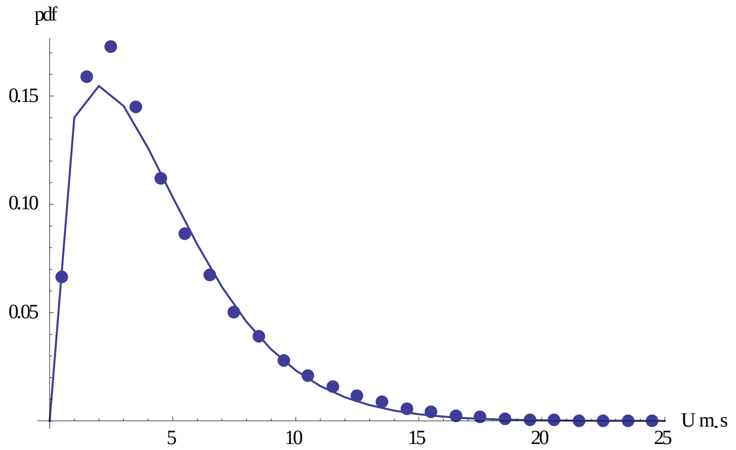


Figure 3.5.1 –Weibull pdf for wind speed at Aqua Alta site. From Mermaid D5_1.

A Vestas V112 offshore wind turbine [http://nozebra.ipapercms.dk/Vestas/Communication/Productbrochure/OffshoreProductBrochure/OffshoreProductBrochure/], characterized by a rotor of 112 m diameter and by a rated power of 3.3 MW is considered as the reference turbine for calculations. It has to be noted that no relevant deviations from the achieved results should be expected from a different reference turbine model. The hub height has been assumed to be 100 m and therefore the Weibull distribution of Figure 3.5.1 has been used for calculations: this assumption is very important due to the fact that wind is strongly affected by height above ground.
The estimated productivity at the site, according to the above mentioned procedure, is less than 1000 equivalent hours, equals to a capacity factor around 11%. Those numbers are, from the investor point of view, not attractive even for on-shore installations, where the impact of foundation, grid connection, installation and O&M costs are significantly lower.

The above mentioned numbers refer to the installation of a single wind turbine. In case of a wind farm, a further productivity decrease in the range of 10 to 20% has to be expected due to wake effects.
The larger the distance between turbines, the lower the wake effects on productivity, the lower the wake induced fatigue loads and the higher the energy losses across cables can be expected, but it has to be taken into account that also the turbine water depth might change by increasing the distance between the machines, and therefore the installation and foundation costs, as well as the visual impact of the farm. Moreover, the extension of the wind farm area may increase the chance of conflicts with other uses.

In order to define an optimal layout, where optimal means achieving the maximum annual energy production, all of these aspects have to be taken into account. In the specific site, being an installation for wind only not an option, a preliminary wind farm layout is suggested in order to provide useful data for potential MUP integration.

Distances in offshore wind turbine spacing can be found in the range of 4 to 12 rotor diameters meaning that, taking again the V112 as the reference turbine, a distance ranging between around 450 and 1350 meters between two machines can be found (Barthelmie et al 2010). Not getting inside the detailed analyses mentioned above, a spacing of 7 rotor diameters (Rivas 2007, Van Bussel) leading to a distance of around 800 m between each machine is taken as the base case. This has to be considered as the minimum reasonable distance between turbines. A further analysis might be carried out for integration purposes, i.e. exploiting turbines structures for supporting cages, investigating the effects of spacing turbines differently, in order to foster synergies with different uses, analyzing different turbine spacing, but at the current stage, a square layout of 800 by 800 meters is proposed as the reference for offshore wind farm layout. The basic layout structure is shown in Fig. 3.5.2.

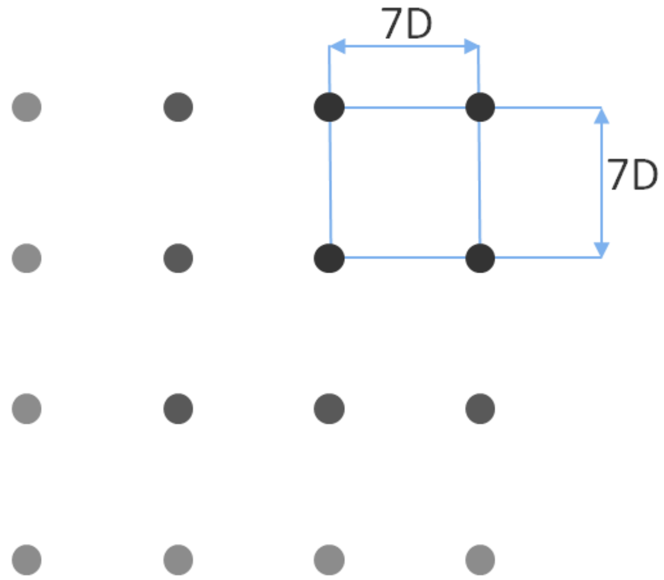


Figure 3.5.2 - Proposed reference layout for the large wind farm.

Neglecting the wake effects, such a single 800x800 m cell, made up of 4 turbines (black), covering 0.64 km^2 would produce 12.7 GWh/y. An extended matrix of 9 machines (see additional 5 machines in dark grey in Figure 3.5.2) would cover 2.54 km^2 and produce 28.5 GWh/y while an array of 16 machines (see additional 7 machines in grey in Figure 3.5.2) would cover 5.76 km^2 and produce 50.7 GWh/y, and so on, neglecting wake effects and cable losses.
From the analysis of met-ocean conditions in Section 2.4.3 it appears clearly that the most interesting winds for energy production comes from the Bora and the Scirocco sectors, approximately perpendicular one to each other, the first one being much more energetic. A detailed assessment of wakes is needed to provide the reference orientation of the wind farm with respect to prevailing wind directions, also depending on how many machines would be installed at the site.
With the aim of minimizing wakes, a slightly skewed layout should be considered.
It has to be noted that, on top of the wind turbines, two other structures will be needed: a met mats tower and an offshore substation to collect the array cables, rise the voltage to MV or HV according to the number of machines and export power to the shore via a single power cable.

B) Small Wind

Generally speaking, a site which is not attractive for utility scale wind is even less attractive for small wind technology, due to higher specific costs per unit power installed, increased wind turbulence and lower wind resource available when decreasing hub height.

Using the logarithmic Prandtl model to estimate wind speed at a hub height of about 25 m, with the hypothesis of a class 0 site, corresponding to open sea without significant waves, the calculated mean wind speed is around 4.06 m/s. For productivity analysis, the same k factor as 100 m Weibull distribution has been assumed, while the A parameter has been calculated to be 4.46 m/s. Taking the horizontal axis Bergey EXCEL 10 wind turbine [http://bergey.com/technical] as a reference, less than 800 equivalent hours have been estimated, around 9% capacity factor. As expected, the number is very low even if compared with traditional onshore installations.

The reference turbine has been chosen according to the following criteria:

- Horiziontal axis, generally providing a higher annual energy production in comparison with vertical axis turbines of the same rated power
- Certified power curve http://www.smallwindcertification.org/certified-turbines/

Small wind turbines are mostly installed as single turbines. Occasionally, a single row of turbines might be found, perpendicularly to the prevailing wind direction. Due to reduced resource at low hub heights, wakes would affect dramatically the investment. This is also the case of Aqua Alta platform where a single line is recommended, perpendicular to the Bora direction. In this case, the distance between turbines could be reduced to 4 diameters. The Excel10 reference turbine has a diameter of 7 m, so that a distance of around 30 m is envisaged. A slight offset angle might be provided with respect to a perfect facing of Bora winds in order to avoid production losses by Scirocco winds, see Fig. 3.5.3 for a potential layout.

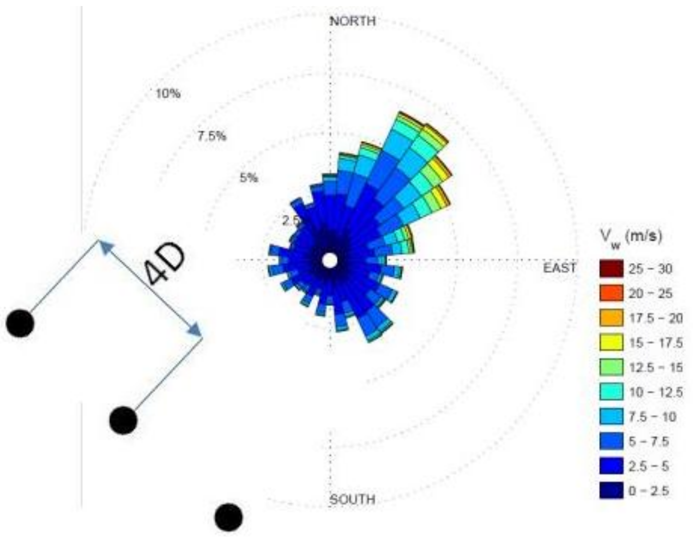


Figure 3.5.3 – Layout and orientation of small wind turbines

Economic data about Large and Small wind technology

Despite the cost estimation is not the purpose of the present paragraph, economic data about small and large wind are given in order to provide all of the elements needed for subsequent analyses. Also, the available incentives for offshore wind energy produced in Italy are briefly commented.

The cost breakdown data for offshore wind projects can be sourced from several publications. Hereby Tab. 3.5.1 reports the figures provided by International Renewable Energy Agency, available for free download from IRENA website [http://www.irena.org/Publications/ReportsPaper.aspx?mnu=cat&PriMenuID=36&CatID=141].
The costs, expressed in 2010 US dollars are reported in Figure -. It has to be noted that foundation costs refer to a bottom fixed installation, not further specified, and that the figures are valid for large wind farms, due to presence in electrical infrastructure of array cables and substation. It should also be noted that, apart from wind turbine, the major costs are related to electrical infrastructure and foundations. These are the key areas to produce synergies on when investigating a multi use platform. Offshore O&M costs can range from 27 to 54 US$/MWh (ECN, 2011).

Tab. 3.5.1 – Capital cost structure of off-shorewind power sytems.

	Share of total cost (%)	Cost (USD/kW)	Sub- Components	Cost share of sub-components (%)
Wind turbine	44	1 970	Nacelle Blades Gearbox Generator Controller Rotor hub Transformer Tower Other	2 20 15 4 10 5 4 25 15
Foundations	16	712	-	-
Electrical infrastructure	17	762	Small array cable Large array cable Substation Export cable	4 11 50 36
Installation	13	580	Turbine installation Foundation installation Electrical installation	20 50 30
Planning and development	10	447	-	-
Total	100%	4 471		

Source: Douglas-Westwood, 2010.

Small wind turbines show a lower degree of standardization if compared to the MW scale ones and this fact affects specific costs. A reference number for a fully commissioned onshore turbine of the size of about 10kW might range from 3.5 to 6 k€/kW, depending on the supplier, according to the authors know how and with no specific reference on the reference model used for productivity estimation. This costs include traditional onshore concrete foundations (or connection to existing structures) and, of course, no expenses for costly offshore connections.
So far, there are no grid connected installations of offshore small wind systems, the costs of submarine cables being not recovered in a reasonable time frame.

The incentive schemes for renewables in Italy have recently been modified [http://www.itabia.it/doc/pdf/DM-rinnovabili-elettriche_6lug2012.pdf, page 39 for new power

plants] from a green certificate scheme to a feed in tariff scheme. Tariff for large (above 5MW) wind farms installed offshore equals to 165 €/MWh fed to the grid. The mechanism to access the incentive is quite complicated and includes incentive reduction auctions, so referring to 165 €/MWh might be a quite optimistic scenario.
Small wind offshore, connected to the mainland, would get a 176 €/MWh fed to the grid.

Wave Energy

In the following, two installations are analysed, the first floating and the second fixed.

A) DEXA

The DEXA device is a Wave Activated Body (WAB) type. It consists of two rigid pontoons with a hinge in between, which allows each pontoon to pivot in relation to the other (see Fig. 3.5.4). The draft is such that at rest the free water surface passes in correspondence of the axis of the four buoyant cylinders (www.dexawave.com). The Power Take-Off (PTO) system consists of a low pressure power transmission technology and is placed close to the centre of the system, in order to maximise the stabilisation force.

Figure 3.5.4 – On the left, the DEXA concept. On the right, a rendering of DEXA wave energy farm (www.dexawave.com).

This device has been selected mainly for the following reasons.

1- Preliminary tests showed that for device length to wave length ratio close to 1.00, DEXA is very effective (Kofoed, 2009; Zanuttigh et. al. 2011); this aspect allows to produce energy also when the sea conditions are not extreme, such as in the Mediterranean site.
2- It is a floating WEC and so it adapts to sea level changes.
3- It is eco-compatible: in fact it has a low visual impact (since it is floating without high emerged part) and a low environmental impact (not necessary toxic anti-fouling painting).
4- It is possible to imagine a multi-use installation, for example the mooring lines can be designed in such a way to be used also as moorings for fish farming and/or to create an artificial sea floor to which sea cages can be connected.

However the DEXA device has some limitations, among them:

1- the low efficiency (not higher than 30%),
2- the wide mutual distance required between devices due to the mooring systems and the device motions;
3- the not modularity –which leads to higher construction costs, more difficult maintenance and replacement operations.

The power production in the site thanks to a DEXA installation is evaluated based on physical tests (a preliminary analysis in Angelelli et. al. 2013).
The device was reproduced based on Froude similitudes, in scale 1:60. It is worthy to remark that the basin depth affects the choice of the future place of installation and the device behaviour, because some effects are not easily reducible (for example friction effect, PTO system, mooring force).
Two models were tested in the shallow water 3D wave basin of the Hydraulics and Coastal Engineering Laboratory at Aalborg University, DK. Each model was 0.95m long (l) and 0.38m wide (b) perpendicularly to wave propagation direction, and its weight was around 4kg.
The models were equipped with a PTO system, which was composed by an air piston and a magnetic displacement sensor both placed in a horizontal position and tightly connected in order to guarantee no relative motion between them. The PTO rigidity was optimized by varying the vertical distance between the PTO system and the model axis (a maximum of 6 rigidities have been analysed). Both models were moored with a “spread” mooring system consisting of four steel chains, each 2.50 m long and linked to the device at the fairlead point and fixed to the bottom with heavy anchors.
The design parameters for the basic experimental configuration are summarized in the following:

- water depth equal to 0.45m (which corresponds to the maximum allowed water depth);
- wave height H_S in the range 0.033-0.167m, peak wave period T_p in the range 0.72-1.87s;
- wave farm line layout: distance between the wave-maker and the devices: 3.60m; mutual long-shore distance between the devices equal to 2.00m or 5b where b is the device width (i.e. the minimum distance according to the mooring system);
- optimal mooring pre-tension level corresponding to a 80% of the total chain length lying on the seabed at the rest (average pre-tension of 0.6 N).

For the configuration described above, the following efficiency (η) trend is derived:

$$\eta = -0.615 \bullet (l/L_p)^2 + 1.3163 \bullet (l/L_p) - 0.3566$$

where l is the long-shore device length and L_p is the peak wave length.
The efficiency is maximum for l/L_p around 1.0, therefore the design of the device is carried out by assuming l/L_p =1 where L_p is derived from a weighted average based on wave frequency of the values of L_p associated to the wave conditions synthesized in the table 2.4.9 in Section 2.4.3.
By calculating the average value of L_p = 30.4 m, the device length l is assumed to be equal to 30 m, and therefore the device width b is imposed equal to 15 m, in order to keep the aspect ratio similar to the proposed Danish prototype and at the same time optimize stability with the squared shaped pontoons.

For each sea state, the power produced by the device is calculated as

$$P = \Sigma_i P_{Wi}\, b\, \eta_i\, f_i$$

being P_{Wi} the available wave power $P_{Wi} = \rho \bullet g^2 \bullet H_S^2 \bullet T_p / (64 \bullet \pi)$, b the device width and f the yearly probability of wave occurrence.
By assuming

- that the power production under Scirocco waves is about 2/3 of the production under Bora waves,
- that there is no efficiency loss due to device re-orientation under oblique waves

each device produces about 3 GWh/year.

If one considers a basic module of 5 staggered devices (as in Fig. 3.5.5) a power production around 15 GWh/year can be achieved.

To make the wave farm more competitive, the following configuration is proposed.

- CALM mooring system to allow a prompt device re-orientation following the incoming wave direction.
- Gaps width equal to 7l in long-shore and to 3l in cross-shore in order to avoid collision between near devices during them re-orientation.
- The wave farm will be composed by 6 lines of devices and 6 devices for the first line, and therefore by a total number of 30 devices, leading to an average annual power production of **89.6 GWh/year**.
- The occupied marine space will be 1350m (long-shore) x 720m (cross-shore), i.e. 0.97km2. The wave farm will therefore consist of 6 modules: 3 modules placed in the long-shore and 2 modules in the cross-shore direction.

It is worthy to remark that:

- the evaluation of the power production has been derived based only on hydraulic efficiency;
- the assumption of perfect re-orientation without any energy losses has been made;
- the proposed wave farm will need: several mooring chains/lines will lead to possible problem for the ship during maintenance operation; at least 30 anchors for the buoys of the CALM mooring system → seabed characteristics have to be considered, for example siphoning phenomena may occur.

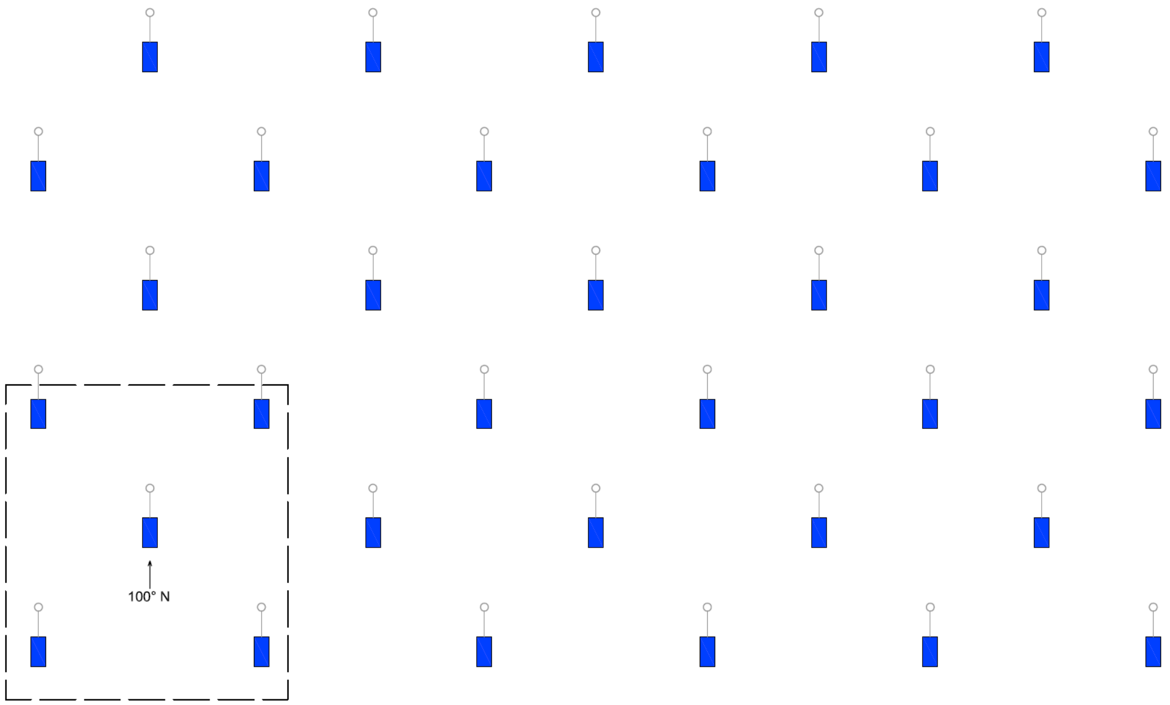


Figure 3.5.5: Layout of the proposed wave farm of DEXA wave energy converters (6 lines in cross-shore direction, 6 device in long-shore direction). A single module with 5 staggered devices is represented by the black dotted line; the wave farm consists of 6 modules.

B) Wave Star

The Wave Star machine draws energy from wave power with floats that rise and fall with the up and down motion of waves (http://wavestarenergy.com). The floats are attached by arms to a platform which includes all the electrical and mechanical parts. The platform stands on legs secured to the sea floor and it is sufficiently high above the water surface, so even the highest waves cannot reach the structure (see Fig. 3.5.6).

The motion of the floats is transferred via hydraulics into the rotation of a generator, producing electricity. The Wave Star is designed with multiple arms (each one with a length at least equal to the main wave length) in order to optimize the power production regardless the incoming wave direction.

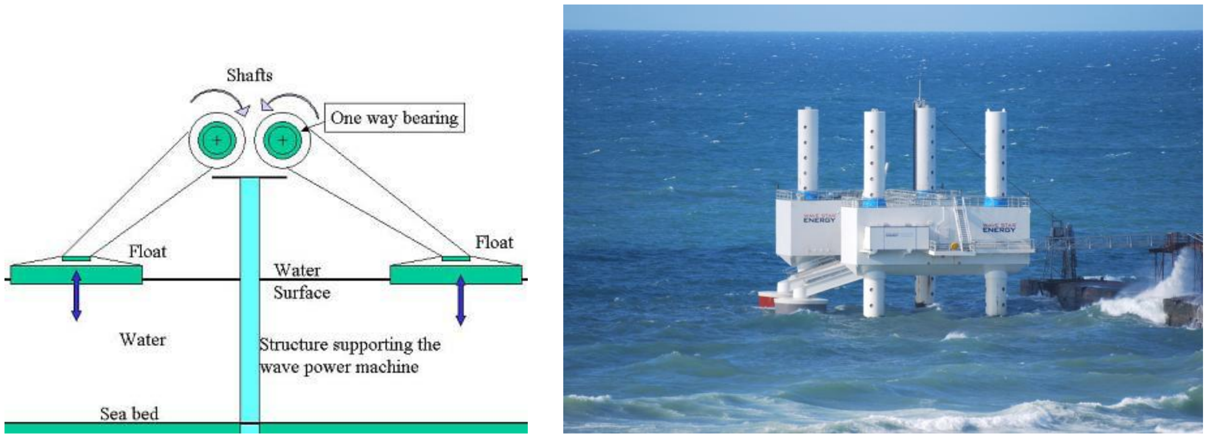


Figure 3.5.6 – To the left, the principle of operation of the Wave Star. To the right, a Wave Star prototype (with only two floaters) installed at Hanstholm (DK).

This device has been selected mainly for the following reasons:

1- it is at an advanced state of progress, since it is already grid connected;
2- it is a point absorber, therefore it can extract energy from all wave directions; this feature is particularly suitable in this site where the energy is associated to two main different wave directions;
3- it is proved to produce energy also for milder wave heights (>0.5m);
4- it is possible to imagine a combined renewable energy installation, for example combined with off-shore wind piles and/or micro-wind.
5- it is possible to imagine a multi-use installation, where the piles can be used for supporting the fish cages.

The Wave Star device has some limitations, among them:

1- it is a fixed installation and the foundation leads to higher environmental impact, may produce liquefaction problems and is usually a high expensive system (as far as construction and transportation are considered);
2- the adaptability to sea level changes is connected to the height of the fixed mooring system;
3- the Wave Star installation consists also of emerged parts which has to be considered for visual impact.

The WaveStar is supposed to be placed in 20-25 m depth and composed by arms up to 140 m long with 20 floaters of 10 m diameter each.

Also for this device, the prediction of the power production is based on physical and numerical data available in the literature (RAMBØLL, 2004).
The model tests reproduced in scale 1:40 a floater of 10m diameter subjected to wave heights in the range 1-5m and wave period 4-8s. The influence of the incoming wave direction on the power production of an array of 5 floaters was also investigated.
From these tests the efficiency (η) trend was derived first as function of H_S

$$\eta_1 = 0.2612 \bullet (H_S) - 0.1306 \qquad 0 < H_S < 1\text{m}$$

$$\eta_1 = 0.0191 \bullet (H_S) + 0.1139 \qquad 1 < H_S < 5\text{m}$$

then also the effect of the wave period T_p was estimated by keeping constant the wave height

$$\eta_2 = -0.0278 \bullet (T_p) + 0.4529 \qquad H_S = 2.5\text{m},\ 4 < T_p < 12\text{s}$$

The overall efficiency η_{TOT} trend used in the calculations reported below is

$$\eta_{TOT} = \eta_1 \bullet \eta_2$$

To evaluate the yearly power performance the wave states reported in Section 2.4.3 have been used. For each sea state, the power produced by the device is calculated as

$$P = \Sigma_i P_{Wi}\, D\, \eta_{TOTi}\, f_i$$

being P_{Wi} the available wave power $P_{Wi} = \rho \bullet g^2 \bullet H_S^2 \bullet T_p / (64 \bullet \pi)$, D the floater diameter and f the yearly probability of wave occurrence.
By assuming that the power production under Scirocco waves is about 2/3 of the production under Bora waves, each floater produces around 230 MWh/year.

Once the power production for each floater is known, the next step consists of the design of the Wave Star layout module (i.e. orientation and number of arms, of floaters, etc.). The maximum number of floaters for each arm is selected as a compromise between arm dimension and power production performance. Based on the experimental report, the power production performance is influenced by:

- the gap width between near floaters; specifically, the greater the gap width, the lower the reduction of power production between one floater and the subsequent one;
- the number of the subsequent floaters for each side of the arm; the maximum number of investigated floater was 5;
- the angle between the arm and the direction of incoming waves; specifically, the larger this angle, the greater the power production.

Therefore it was selected to design the WaveStar module assuming

- 5 floaters for each side of the arm, i.e. 10 floaters for each arm;
- the gap width between the floater equal to 5m;
- 3 arms with the central arm oriented at 100°N and an angle of 120° between them; based on the two conditions above, each arm is 80m long and 8m wide (to allow the placement of the 5 m diameter piles and the access to the instrumentation).

The average yearly power production is then estimated under the following assumptions

- power reduction due to arm inclination with respect to the incoming waves: 50% for the central arm since the angle between the directions characterized by higher energy density (70° and 130°) and the arm (100°) is about 30° only; a similar reduction of 10% for the other two arms;
- same efficiency for the all floaters along an arm.

For the basic module of 3 arms (Fig. 3.5.7) a power production of around 9 GWh/year is obtained.

To make the wave farm more competitive, the following configuration is proposed.

- The gap width between two module equals the arm length (80m) both in long-shore and in cross-shore direction to allow maintenance operation and possibly implementation of combined fish-farming options.
- The wave farm is composed of 15 modules (5 modules long-shore and 3 modules in cross-shore), for a total power production of **133.7 GWh/year**.
- The occupied marine space will be 1200m (long-shore) x 720m (cross-shore), i.e. **0.86km^2**.

It is worthy to remark that:

- the evaluation of the power production has been derived based on hydraulic efficiency only;
- the assumption of negligible losses of incident wave energy along the arm has been made;
- the proposed wave farm will need 60 foundation piles (at least 4 for each module) → seabed characteristics and environmental impacts have to be considered.

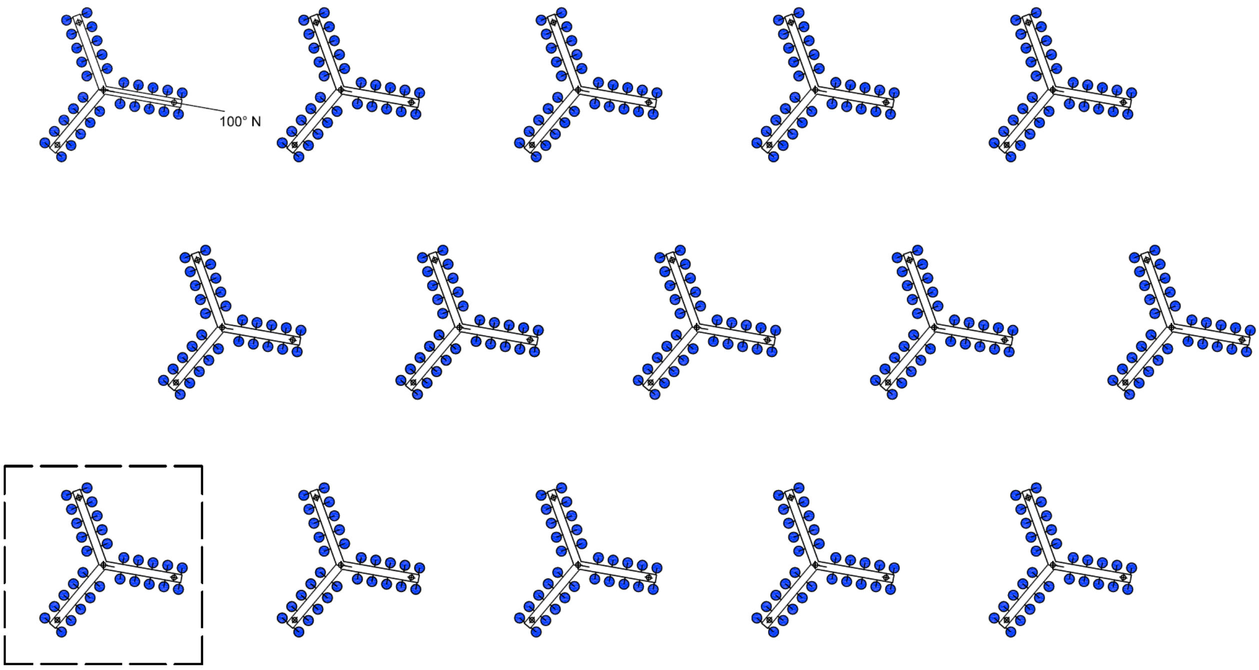


Figure 3.5.7 - Layout of the proposed wave farm of Wave Star wave energy converters, composed by 15 modules. Each module (in the black dotted line box) consists of 3 arms with 5 floaters for each side.

Suitability for aquaculture development

The Mediterranean Sea has been hosting the major part of aquaculture production of Mediterranean Sea bass (*Dicentrarchus labrax*) and gilthead Sea bream (*Sparus auratus*) for over 30 years now. The reported favorable conditions for raising these species in the Mediterranean Sea, the long experience gained in cultivating them, the ever increasing demand in the global markets for these species (either it be for traditional festive dinners in the Med or for sushi-toppings in the American and Asian continents), along with the existing strong conflict for space by many users in coastal areas and fish health issues arising in closer-to-the-shore areas, have led to the notion that moving aquaculture further offshore and combining it with other activities, such as energy-converters, will create more cost-effective synergies.

As a first step in assessing the Acqua Alta site for its potential as an aquaculture site for sea bass and sea bream farming, Kefalonia Fisheries SA has evaluated data on temperature, salinity and biochemical parameters (phosphates, nitrates) made available from the MEDAR/MEDATLAS II project, via UNIBO. The data provided, refers to mean values of data collected over multiple years.

This data was incorporated in a computational model developed by Kefalonia Fisheries SA over the years for predicting production according to physicochemical parameters, and three different scenarios based on different environmental condition profiles were investigated for each species. Temperature is the most important factor affecting productivity (when all other parameters are within the range of tolerance of the species), and the data used for our purpose was the temperature at 5m depth:

Sea bass:

- Production of Sea bass of average marketable size (~350 gr) starting with stocking of juveniles of average weight of 2 gr, in March
- Production of Sea bass of average marketable size (~350gr) starting with stocking of juveniles of average weight of 2 gr, in June
- Production of Sea bass of average marketable size (~350gr) starting with stocking of juveniles of average weight of 2 gr, in September

Sea bream:

- Production of Sea bream of average marketable size (~350 gr) starting with stocking of juveniles of average weight of 2 gr, in March
- Production of Sea bream of average marketable size (~350gr) starting with stocking of juveniles of average weight of 2 gr, in June
- Production of Sea bream of average marketable size (~350gr) starting with stocking of juveniles of average weight of 2 gr, in September

The results for the Acqua Alta site are reported in Tab. 3.5.2 and compared with the equivalent on-growing periods for sea bass and sea bream farming in the South-eastern Mediterranean in Tab. 3.5.3.

As it can be seen by comparing the two different sites, fish farming of the species at the Acqua Alta site will require a significantly longer time than the South-Eastern Mediterranean site, and will therefore be a less cost-effective investment.

Tab. 3.5.2 On-growing periods for sea bass and sea bream farming in the Acqua Alta site.

North Adriatic Temperatures							
	Juvenile Stocking month	AVG Start weight (grams)	On-growing period	AVG Final weight (grams)	F.C.R	SW Temperature ('C)	
						AVG	STDEV
Bass	March	9	18	358	1,40	18,6	3,5
	June	2	25	365	1,86	18,3	3,4
	Sept	2	24	367	1,56	18,3	3,5
Bream	March	11	19	385	1,63	18,8	3,5
	June	2	25	365	2,11	18,3	3,4
	Sept	2	24	367	1,76	18,3	3,5

Tab. 3.5.3 On-growing periods for sea bass and sea bream farming in the South-eastern Mediterranean.

South-Eastern Mediterranean Temperatures							
	Juvenile Stocking month	AVG Start weight (grams)	On-growing period	AVG Final weight (grams)	F.C.R	SW Temperature ('C)	
						AVG	STDEV
Bass	March	9	13	363	1,12	21,8	3,9
	June	2	14	372	1,06	22,6	3,9
	Sept	2	14	358	0,96	22,4	3,7
Bream	March	11	11	360	1,07	22,5	3,8
	June	2	14	365	1,22	22,6	3,9
	Sept	2	14	367	1,08	22,4	3,7

Following this preliminary assessment of the site potential for aquaculture, detailed sets of data should be acquired for the following parameters, so that a final assessment can be delivered:

- Temperature (annual profile)
- Salinity (avg)
- Dissolved Oxygen Level (seasonal)
- Chlorophyl levels (seasonal)
- Nitrates (seasonal)
- Phosphates (seasonal)
- Bathymetry
- SW currents (occurrence, strength and direction)
- Waves (directions, avg and max wave heights)
- Sediment type (below and around the area where the cages are to be sitted)
- Potentially harmful predator species (fish, mammals or birds).
- Data on urban & industrial effluent/waste
- Heavy metal run-offs
- Other metocean data that might affect design of the farm

Data should cover a time span of at least 3 years.

Basic Requirements that have to be considered for establishing and operating a sea bass/sea bream fish farm at any site are the following:

- Depth: in order to secure good health for the fish, the depth of the sea has to be at least 3 times the depth of the nets of the sea cages. This allows for adequate renewal of the water around the cages and proper dispersal of the material that tends to accumulate underneath the cages. Therefore, in the case of a net depth of at least 9 meters, the total depth of the site must be at least 27 meters
- Individual cages must be at least 8 meters apart from each other, to allow good circulation of clean water between and within cages
- Mooring structures for other activities (WECs etc) can be used for securing only part of the sea cage mooring systems, as each sea cage park requires multiple anchoring points.

In the suggested plan, the following issues were taken into account, given that the fish farm is designed with a 2’000 tons annual production capacity in mind:

- Sea cages suggested to be used have a diameter of 32 meters.
- For the production of 2’000tons fish, 56 cages of this diameter are required.
- Around each cage there has to be a rectangular frame of ~40 meters side length, allowing for operations that need to take place at each cage. This frame also allows for the required distance between cages for good circulation of water
- Cages must be laid out in cage parks consisting of parallel rows of sea cages, for better handling and more efficient production
- The size of each park is not unlimited, as automatic feeding systems can only be effective up to a certain distance (~300-400 m). Therefore, the cage that is furthest away from the automatic feeder cannot exceed this distance.
- The best lay out of cages in water space is in 3 parks, which will be positioned each on one side of the MUP-in the case of a single use platform (stand-alone), a floating structure/platform is still needed at the same position
- The platform (either MUP or single use floating structure) will accommodate the following: automatic feeder, feed storage room, equipment storage room, staff accommodation facilities
- The size of the platform has to be at least 300 m2: ~150 m2 for the automatic feeder and ~150 m2 for the other purposes.
- The feed storage space must be able to accommodate 150 tons of feed at any time. This allows for a frequency of transportation of feed from land to the offshore platform once every 4 days.
- Space between neighboring parks, according to legislation, must be at least 100 meters. This also allows for free sailing of the harvesting and other vessels.
- The mooring system is determined by the depth of the site: must be 3 x the depth of the site. In the case of the Adriatic site, mooring chains should be 50m long.
- Each cage must be secured with mooring devices at each corner exposed to the sea. In the case of a MUP, only some points of the other devices’ anchoring system can be used to secure the fish farm’s mooring systems.

The design that better suits all of the above can be seen in Fig. 3.5.8.

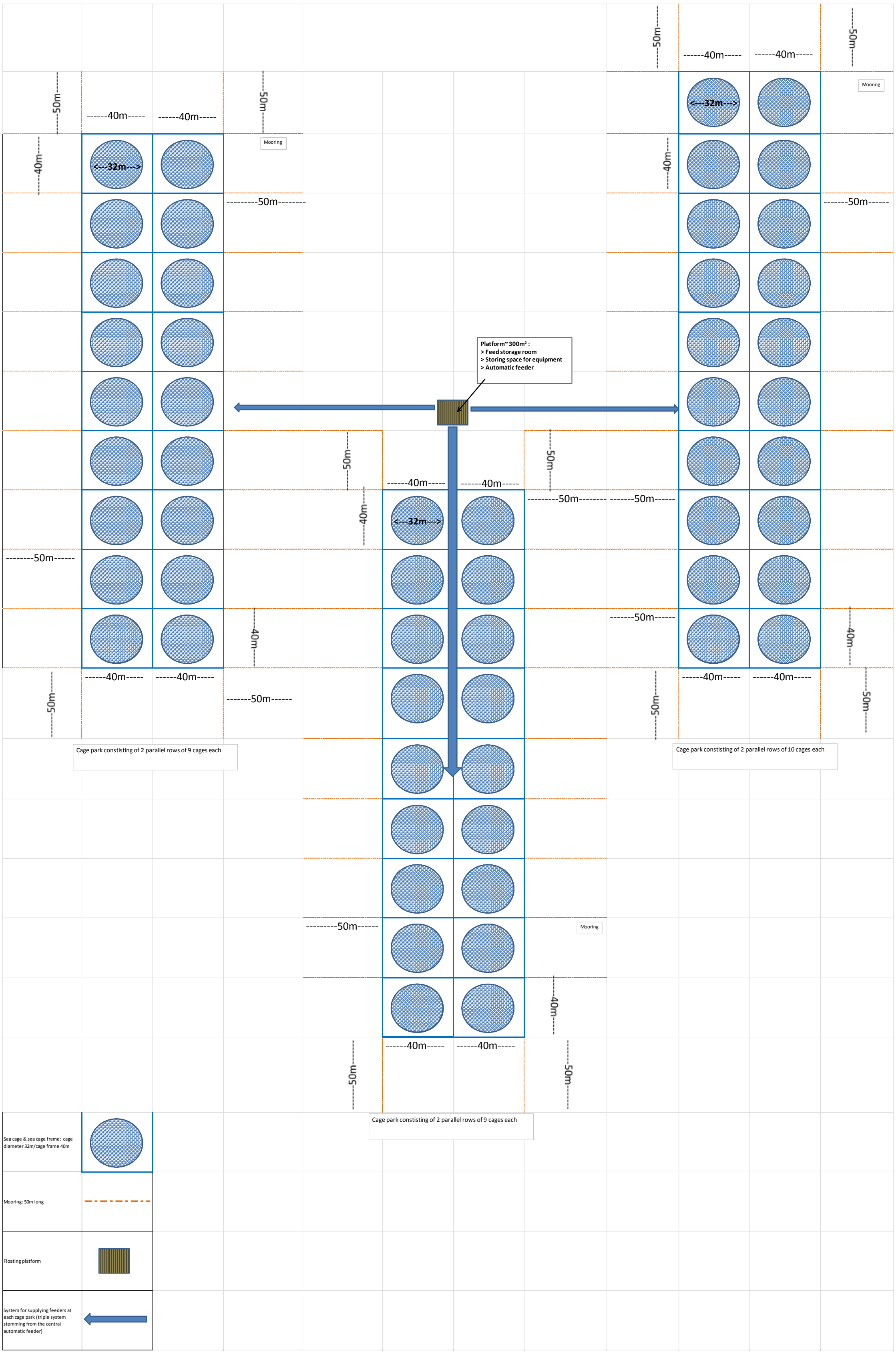


Figure 3.5.8 – Layout proposed for the fish farm.

Another option that could be considered as an alternative to sea bass farming is shellfish production, particularly mussels (Mytilus galloprovincialis). Mussel farming is one of the most economically important aspects of global aquaculture and has increased in both the global production and value (Fao 2004). Considering only the Mediterranean Sea, mussel production is over 700,000 ton y^{-1} (FAO, 2000). Mussel farming is in general less impacting that fish farming as mussels feed on natural resources (suspended particles) and are not sustained by any additional intensive feeding (Inglis et al., 2000, Danovaro et al 2004).

Use of the platform

A specific *threshold analysis* will be applied to alternative combinations of uses (i.e. wave, fish, wave and fish, wave and fish and wind) in order to identify the minimum IRR as dependent on (unknown) environmental benefits. Indeed, a *threshold analysis* is a methodology which calculates the minimum value to be attached to (unknown) environmental benefits in order to justify the choice of a particular option. In particular, a preliminary *threshold analysis* for a wave - fish - wind MUP does not show outstanding IRR, although it seems to be feasible (i.e. IRR at 2%) if combined with ecological structures which improve water quality, reduce alien species, improve biogenetic habitats, increase primary production, overall evaluated at 1 euro/m2. This is smaller than the average GDP per m2 in the Veneto Region (i.e. 130,634.3 Million euros/18,378 Million m2 which is around 7 euro/m2). Both current incentives to energy and current subsidies to aquaculture are applied, although they might be changed in the future. THESE REUSLTS ARE EXPLANATORY ONLY. **Note** that there are no conflicting uses: both tourism routes to Croatia and maritime routes to Ancona and Trieste are far away from the Acqua Alta platform. However, tourism activities in the near coast might be affected by fishery activities.

Feasibility criteria

Criteria	Type of judgment
Renewable energy potential	Yes Wave: Yes, Pw=4 kW/m Wind: Not off-shore plant (to be further verified), vw=4.5 m/s – micro wind possibile solution Tide: No
Aquaculture potential	Yes Fish farming: sea-bass and sea bream Minimum installation depth: 27 m

Synthesis of the multi-purpose and single purpose concepts to be explored

Name	Wave		Wind		Fish farm	Electricity connection	
	WaveStar	DEXA	Large	Small		Standing Alone	Connected to Grid
MUP 1	X		X	X	X	X	
MUP 2	X		X	X	X		X
MUP 3	X			X	X	X	
MUP 4	X			X	X		X
MUP 5	X		X		X	X	
MUP 6	X		X		X		X
MUP 7	X				X	X	
MUP 8	X				X		X
MUP 9	X		X				X
MUP 10	X			X			X
MUP 11		X	X		X	X	
MUP 12		X	X		X		X
MUP 13		X			X	X	
MUP 14		X			X		X
MUP 15		X	X				X
SUP 1	X						X
SUP 2		X					X
SUP 3					X		X

Preliminary ranking of the multi-purpose and single purpose concepts to be explored

Criteria	Type of judgment	MUP 1	MUP 2	MUP 3	MUP 4	MUP 5	MUP 6	MUP 7	MUP 8	MUP 9	MUP 10	MUP 11	MUP 12	MUP 13	MUP 14	MUP 15	SUP 1	SUP 2	SUP 3
Environmental impact	Score:	2,93	3,30	2,81	3,17	2,80	3,17	2,62	2,98	2,80	2,98	2,63	2,98	2,54	2,92	2,85	2,89	2,67	2,23
	• Use of marine space:	3,25	3,25	3,00	3,00	3,17	3,17	2,83	2,83	2,50	2,33	3,17	3,17	2,58	2,58	2,58	2,17	1,92	1,75
	• Wind piles/devices dimension	3,5	3,5	3	3	3,5	3,5	2,5	2,5	3,5	3	3	3	2	2	3	2,5	2	1,5
	• Size of energy farm:	3,25	3,25	3	3	3	3	3	3	3	3	3,5	3,5	2,75	2,75	2,75	3	2,75	1
	• Size of aquaculture farm:	3	3	3	3	3	3	3	3	1	1	3	3	3	3	2	1	1	2,75
	• Foundation type (moorings….fixed):	3,5	3,5	3,5	3,5	3,5	3,5	3,5	3,5	3,25	3,25	2,5	2,5	2,5	2,5	2,25	3,5	2,25	1,75
	• Materials (including toxic paintings):	3	3	2,75	2,75	3	3	2,5	2,5	3	2,75	3,5	3,5	3,25	3,25	3,5	2,75	3,5	1,75
	• Creation of habitats for native species:	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,5	2,5	2,25	2,25	2,25	2,25	2,5	2,25	2,5	1,75
	• Impacts on native habitats and species:	4	4	4	4	4	4	4	4	3,5	3,5	3	3	3	3	2,5	3	3	3
	• Impact on the coast:	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2	1,75
	• Inclusion of exposed components/parts:	2,5	2,5	2,5	2,5	2	2	2	2	2	2,5	3	3	3	3	3	2,5	2,25	1,5
	• Noise /Vibration:	3,5	3,5	3,5	3,5	3	3	3	3	3	3,5	2,75	2,75	2,75	2,75	2,75	3	2,25	1,75
	• Aesthetic impact:	4	4	3,25	3,25	4	4	3	3	4	3,25	2	2	2	2	2,25	3,25	2	1,5
	• Local energy storage/use:	1	5	1	5	1	5	1	5	3	5	1	5	1	5	5	5	5	5
	• Maintenance:	3,00	3,00	2,92	2,92	2,67	2,67	2,50	2,50	1,75	1,92	3,50	3,42	3,33	3,50	2,75	2,17	2,75	3,00
	• Transportation:	3,75	3,75	3,5	3,5	3,75	3,75	3,5	3,5	1,5	1,5	4	3,75	3,75	3,75	2,5	2,5	2	3
	• Fouling:	2	2	2	2	2	2	2	2	2	2	3,75	3,75	3,75	3,75	3,75	2	3,75	2,5
	• Material durability/feeding:	3,25	3,25	3,25	3,25	2,25	2,25	2	2	1,75	2,25	2,75	2,75	2,5	3	2	2	2,5	3,5
Risk	Score:	3,28	3,61	3,11	3,44	2,90	3,24	2,69	3,03	2,74	2,72	3,22	3,44	2,93	3,26	3,17	3,06	3,39	3,44
	• Structural failure:	3,08	3,08	2,83	2,83	3,08	3,08	2,58	2,58	2,58	2,17	3,92	3,58	3,17	3,17	3,50	2,67	3,42	2,83
	• Modular or single/ rigid structure:	3,5	3,5	3,5	3,5	3,5	3,5	2,75	2,75	3	2,5	3,5	3,5	3	3	3,25	3	3	2,5
	• Geotechnical failure (liquefaction):	3,75	3,75	3	3	3,75	3,75	3	3	3,75	3	3,25	3,25	2,5	2,5	3,25	3	2,5	2,5
	• Moorings:	2	2	2	2	2	2	2	2	1	1	5	4	4	4	4	2	4,75	3,5
	• Power failure:	2,25	3,25	2,00	3,00	2,13	3,13	2,00	3,00	3,13	3,00	2,75	3,75	2,63	3,63	3,75	3,50	3,75	3,25
	• Power take off/feeding:	2,5	2,5	2	2	2,25	2,25	2	2	2,25	2	3,5	3,5	3,25	3,25	3,5	3	3,5	2,5
	• Local energy storage/use:	2	4	2	4	2	4	2	4	4	4	2	4	2	4	4	4	4	4
	• Pollution:	4,5	4,5	4,5	4,5	3,5	3,5	3,5	3,5	2,5	3	3	3	3	3	2,25	3	3	4,25
Costs	Score:	3,54	3,71	3,13	3,29	3,38	3,54	2,92	3,08	2,75	2,67	3,71	3,88	3,25	3,58	3,06	2,63	3,33	2,85
	• Installation depth:	3,5	3,5	3	3	3,5	3,5	3	3	2	2	4,25	4,25	4	4	4	2,25	4,25	3,75
	• Materials:	4	4	4	4	4	4	4	4	3,25	3,25	3,5	3,5	3,5	3,5	2,75	3,5	3	2,5
	• Power extraction and storage:	1,50	3,50	1,50	3,50	1,50	3,50	1,50	3,50	2,75	3,75	2,00	4,00	2,00	4,00	3,88	4,25	4,25	3,88
	• Power take off type:	2	2	2	2	2	2	2	2	2,5	2,5	3	3	3	3	2,75	3,5	3,5	2,75
	• Local energy storage/use:	1	5	1	5	1	5	1	5	3	5	1	5	1	5	5	5	5	5
	• Moorings:	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	1,5	1,5	4,5	4,5	4,5	4,5	3,75	1,5	4,75	3
	• Maintenance:	5	4	4	3	4	3	3	2	2	2	4	3	3	2	2	1	1	1
	• Transportation:	5	5	4	4	5	5	3,75	3,75	5	3,5	4	4	2,5	3,5	2	3,25	2,75	3
	Total (using equal weights)	9,75	10,61	9,05	9,91	9,08	9,94	8,23	9,10	8,28	8,37	9,56	10,30	8,72	9,76	9,08	8,57	9,40	8,53

Note that the rankings of MUPs and SUPs have to be separately considered.

3.5.2 Preliminary platform design and planning

Structural support and design

The foundations of the large wind turbines (Vestas V112), given the properties of the bottom soil and the water depth, are foreseen as monopiles. It is also to be evaluated the possibility of using innovative methods such as bucket foundations (suction caissons).
The small wind turbine (Bergey Excel 10) is usually installed on a guyed-lattice tower, which is available in heights of 18 m to 49 m. Tilt-up versions of these towers are available for sites without crane access in heights up to 30 m. Self-supporting lattice towers and monopile towers are also available. Self-supporting lattice towers are available in heights of 18 m to 49 m and monopile towers are available in heights of 18 m to 37 m. In this design, it is foreseen to install the turbines on the fixed Wave Star structure, i.e. along the arms.
The Wave Star energy converter platform is sustained by piles, driven in the soil.
Mooring devices of the DEXA wave energy converters and fish cages shall preferably be obtained by driving small piles, given the muddy bottom, instead of using standard anchoring methods.

Off-shore energy storage and/or transmission systems

Stand Alone Solution

The offshore wind connection represents the major cost. In presence of a limited resource, it might be impossible to recover the capital costs in a reasonable amount of time. In this frame, a stand-alone configuration, i.e. not connected via subsea cable to the mainland, could be considered.
This is for example the case data acquisition buoys, where the energy is supplied by PV panels, or of some oil and gas platforms, where the local energy needs are supplied by conventional thermal generation (due to availability of the fuel, space requirements and reliability issues) and the platform's electric system is fully independent from that of the neighboring countries.
It has to be noted that this concept might be worth to be investigated only in the case of the Mediterranean, where in the other three sites the renewable resource, mainly wind, is extremely interesting for energy export and could allow to cover subsea cables costs in a reasonable timeframe: this configuration has in fact been suggested in two out of four possible MUP configurations in Mediterranean, in the frame of the previous chapter.
It is very important to point out that in the stand alone case, the key driver to build an offshore infrastructure, as opposite to the Atlantic site, is everything but energy production: aquaculture, logistics and even tourism might drive the realization of offshore infrastructures.

Potential advantages of the stand-alone MUP are:

- substation and export cable costs are not needed to be addressed and margins of reduction might also rise from array cables, depending on the extension of the MUP;
- being the existence of the platform necessarily driven by different uses, i.e. not only the single use energy substructures are in place, synergies might arise from foundation sharing, also being a relevant element of the final cost;
- possibility of displacing offshore any operation, using renewable energy instead of diesel fuel and therefore fostering a greener process. Concerning this, in the stand alone case, the incomes to be addressed by renewable production are actually to be considered as "avoided expenses" rather than active incomes (no energy is sold to the grid), assuming that the renewable energy substitutes conventional diesel engines potentially located on the offshore MUP, therefore saving fuel costs. A reference cost for the energy produced by diesel

engines on Italian islands not interconnected with mainland ranges between 180 and 300 €/MWh.

On the other hand, in case the system is fully autonomous, some kind of energy storage system will be needed to manage the power balance on the MUP. Figure 3.5.10 shows the conceptual of a stand-alone MUP from the electrical point of view: theoretically, all kinds of renewable energy generation, namely wind, wave and tidal energy might be present at the site. All of the converters, starting from local resource, produce electric energy (blue arrows "+") and inject them into the local energy system. This production is variable and not fully predictable. In order for the system to be stable, the power consumption of all of the local loads (red arrow "-"), deriving from aquaculture operations, lighting and any other offshore use must be equal to generation. This is of course impossible due to unpredictability of renewable generation and non shiftable needs of energy. In order to ensure the power balance of the local system, an energy storage system must be installed on the platform. The energy flux across the energy storage will be bi-directional, i.e. accumulate or release stored energy according to the actual conditions at the site.

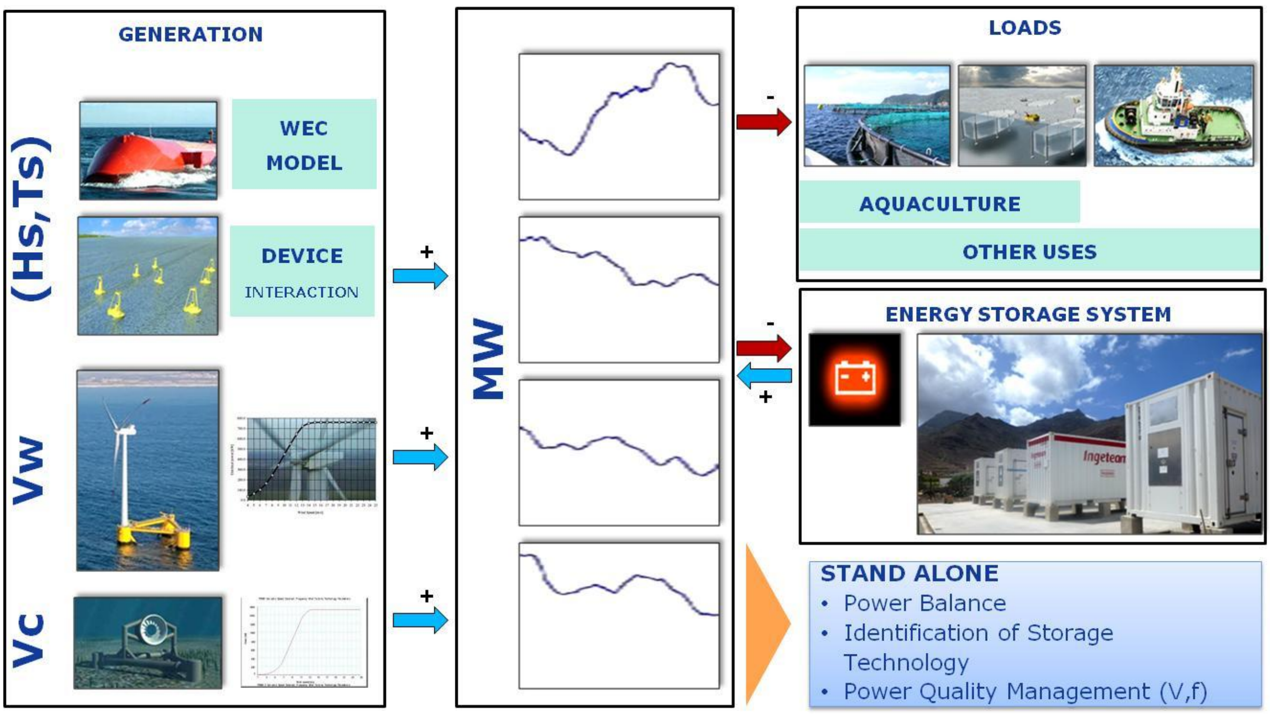


Figure 3.5.9 – Conceptual of a stand-alone energy system for MUPs.

In order to keep the stand alone MUP electrical system stable, a power quality management system is required to provide all of the services necessary to sustain voltage and frequency.
This services are:

- primary reserve
- secondary reserve
- tertiary reserve
- voltage regulation

The identification of the most suitable storage technology has to take into account the capability of the storage system itself to provide all of this services mentioned above, for the needed amount of time, see Fig. 3.5.10.
In order to assess this capability, directly linked to the amount of energy storable inside the system itself, a detailed assessment is needed in terms of:

- aquaculture power consumption at the site and typical uses across the day
- time-series-based renewable energy power production

The analysis of the time series will provide information on the most suitable technology in terms of Power and Energy capacity and suitability to cover a specific amount of power cycles (charge/discharge). Figure – shows a reference map of available storage systems [source: http://www.iec.ch/whitepaper/pdf/iecWP-gridintegrationlargecapacity-LR-en.pdf].

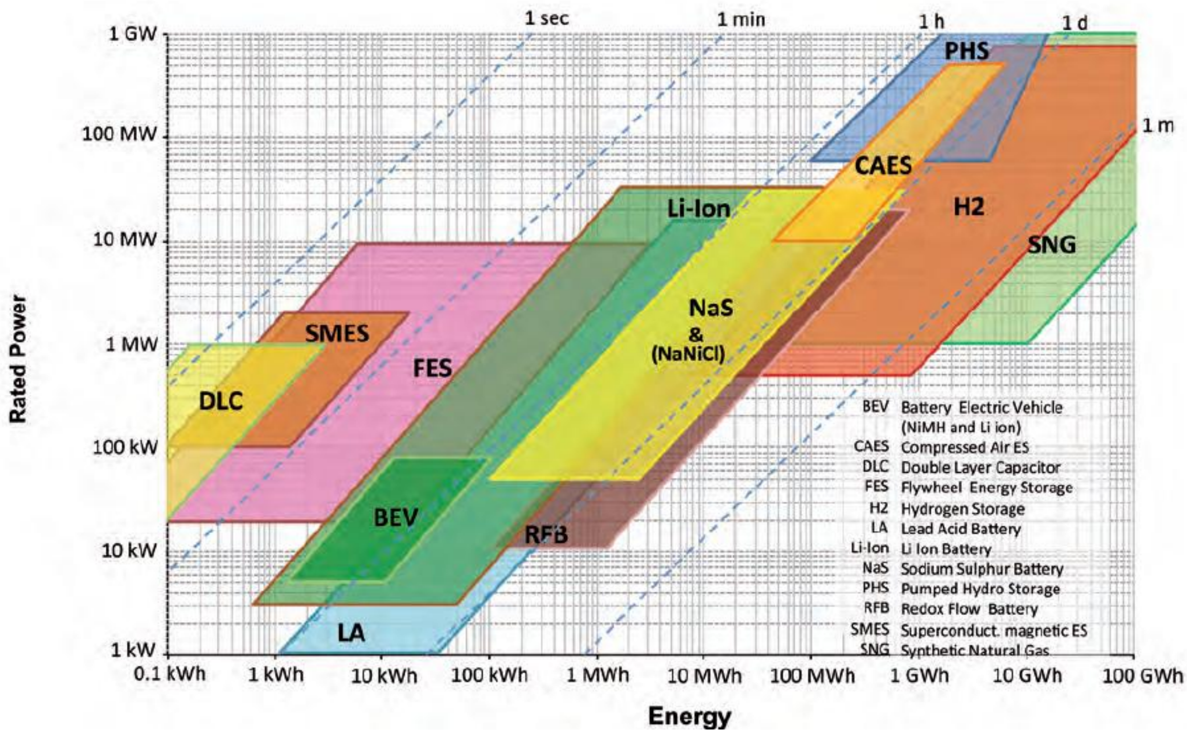


Figure 3.5.10 – Energy storage system classification

In Aqua Alta site, the following stand-alone MUPs concepts are suggested:

- MUP 2. Wave-star + micro-wind + fish farm. Standing alone solution.
- MUP 4. DexaWave + fish farm. Standing alone solution.

The main needs to be expected at Aqua Alta site, according to preliminary communications between Enel and aquaculture experts inside Mermaid partnership will be for:

- automatic fish feeding system,
- platform crane,
- ice producing machines to kill fishes and deliver them to the shore,
- electric boats and floating vehicles,
- lighting and ancillary services (communication, data acquisition, heat pumps).

The above mentioned uses are currently under investigation in order to define the best layout and operations to be carried out the MUP. Time series analysis of the loads and of renewable energy

production will also be investigated as soon as the size of the energy production farm will be identified.
It has to be noted that storage system and other MUPs electrical components should be located on the same platform hosting aquaculture fish food and feeding system.
In any case, in order to ensure reliability of the aquaculture process, a backup power source to cover the low resource prolonged weather windows at the site will be taken into account and investigated.

Grid Connected Solution

Five different grid connected solutions have been suggested:

- MUP 1. Wave-star + microwind + fish farm. Energy transfer to shore.
- MUP 3. DexaWave + fish farm. Energy transfer to shore.
- SUP 1. DexaWave. Energy transfer to shore.
- SUP 2. WaveStar. Energy transfer to shore.
- SUP 3. Fish farm. Energy transfer from shore.

There are several ways to connect an offshore platform, or farm, to the mainland. The connection might be based on MV, HVAC or HVDC, according to the installed capacity and distance to shore. The solution has to be evaluated from case to case, but reference criteria are synthesized in Fig. 3.5.11.

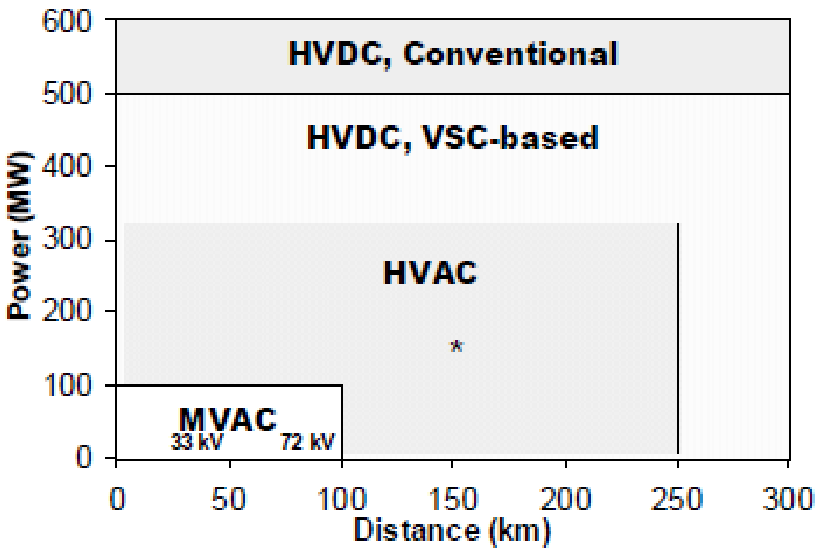


Figure 3.5.11 – Reference distances and capacities for different offshore connection solutions.

While the exact size of the farm is being identified, it can be estimated that the Adriatic sea MUP will fall into the MVAC category. Despite this, it has to be noted that for capacities above some MV, an HV substation on the mainland will be required to obtain enough capacity for energy transport.
A first key point to be addressed is that, in case a MUP is going to be developed, or in case of SUP3, the water depth needed for aquaculture is at least 27 m, meaning that distance to the closest HV substation will increase from about 22 (Venice or Chioggia) to 35 km (Chioggia), see Fig.

3.5.12. In case of SUP1 and SUP2, the wave farm might be realized in proximity of the existing Aqua Alta tower and therefore 22 km of MV connection will be needed.
In any case, an offshore substation will be needed in order to collect array cables from different devices and to increase voltage, still in the MV range, for power export. Also, the substation will be needed to include switchgears, control apparatus, compensation of reactive power and so on.

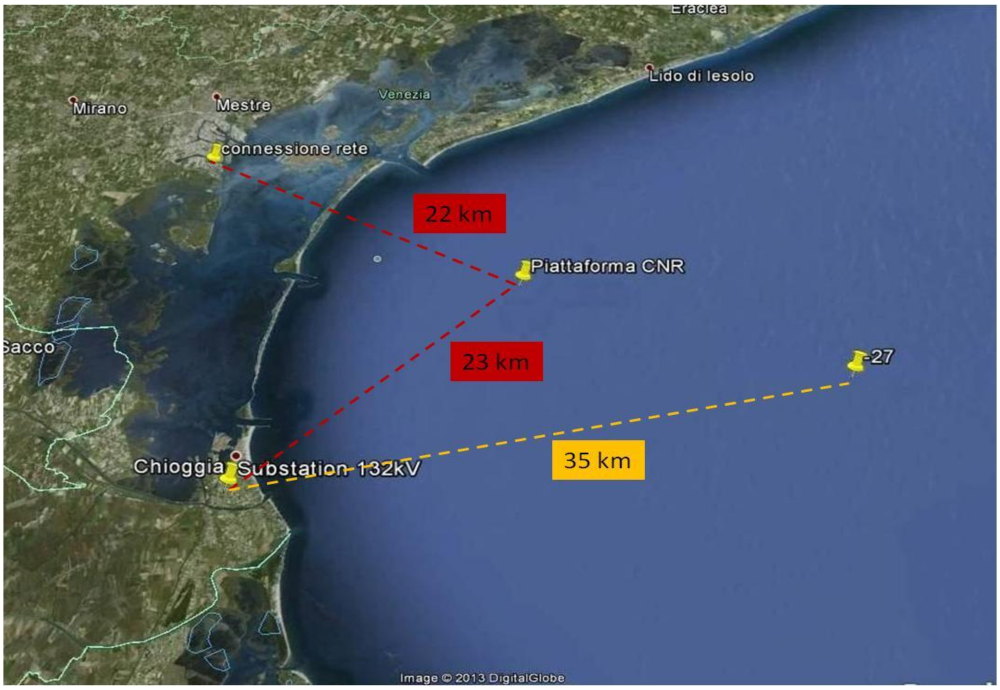


Figure 3.5.12 - - Distance of the two potential sites from the closest HV stations.

Transport and logistical analyses

The local metoceanographic climate is relatively mild, allowing easy transport and logistics. According to the data presented before (see Section 2.4.3) the significant wave height is on average smaller than 0.25 m, 0.5 m and 1.0 m respectively for 141, 248, 324 days per year. Thus for the installation and the maintenance long working time intervals are expected.
A further point to be considered is that the distance of the platform from coastal areas is of the order of 20 km. Given an average speed of service vessels of about 10 kn, the platform can be reached in less than 1 hour. If the service port/berth is located inside the lagoon, it is however to be considered that strict speed limits exist in internal channels.

The vessels required for the operation of the fish farm are 3:

1. Harvesting vessel-can be substituted by an automatic harvesting system, but such a choice will increase the cost of investment dramatically
2. Feeding vessel-apart from the automatic feeder, a feeding vessel must be available for feeding cages with fish which has been stocked recently (previously in hatchery)
3. Vessel for transporting staff & feeds

It is suggested that all fish farming operations are kept as they are in inshore fish farming (i.e. daily commuting of staff to the cage farm vs residing on the MUP, packaging and processing of fish at inland facilities etc).

The most demanding equipment to be considered when analyzing transport and logistical problems may be the transportation of the wind turbine/s. The large wind turbine selected is the Vestas V112. In terms of weight, height and width, all its components comply with local limits for standard transportation, and no components with weight above 70 t is expected. It can be handled by different installation vessels.

Installation, operation, maintenance and decommissioning

For fish farming.

Operation: As described above, for operation purposes of the fish farm, the main requirements that have to be fulfilled are those of space availability in between adjacent sea cages and neighboring cage parks (which have been incorporated in the proposed design). Operations include feeding (in cases where the automatic feeder is not used), harvesting and daily surveillance of proper function. No special requirements other that the ones mentioned at the beginning occur.
Maintenance: There are no major maintenance works needed to be done at the fish farm, except for the occasional change of the nets at the cages (this can take place every 3-8 months depending on the efficiency of the water currents to naturally protect nets from fouling and the net's mesh size). Change of nets does not require special equipment or vessel, other than the ones used in daily operations.
Decommissioning: When decommissioning the site, the cages are simply transported by vessel to the shore, where they can be dismantled. The only thing left behind is the concrete blocks from the mooring systems of the fish farm, which are highly probable to have formed substrata for ecosystem enhancement.

For the wave farm:

Installation: For the fixed farm (Wave Star), the installation requires first of all the transportation of the piles to be driven into the seabed. Once the fixed structure mounted on the piles is stable, it will be then possible to connect the floaters, that should be transported on a vessel and mounted locally. The size of the piles depends on the force acting on the system and on the geotechnical characteristic of the seabed. It is basically suggested to use the same piles as for the selected VESTAS wind turbine, so that they may be used at least partially (i.e. the central pile in the module) to support a large scale wind turbine.
In case of a floating farm, the devices have to be prepared inshore and then reach the site by floating moored at vessels. At the site, each device will be connected to a buoy, anchored to the seabed by means of steel chains, ropes and concrete blocks at the seabed. Furthermore each device will be supplied with two mooring lines in the rear side. The challenging aspect will be to combine the design of the mooring lines with the design of the cables and ropes needed for the fish farm, and also to optimize the moorings for minimizing the environmental impact.
It is particularly important during the wave farm layout installation to maintain the specific distances among them as reported in the preliminary design above. These distances will allow a multi-use of the park and at the same time simplify future ordinary and extraordinary operations.
When the wave farm layout is completed, each device/module will be supplied with a Power Take Off system (PTO) to be connected to appropriate hubs and then cables for power export to shore in case a non-standing-alone solution has been selected.
Operation: The main features which can compromise the power production performance are

- the fouling on the floating devices or on the floaters in case of the fixed installation; a twice-per-year check of the anti-fouling painting is required;
- the PTO, to be periodically controlled
- the degradation of the materials especially rubber-like such as floaters,
- the status of the necessary liquids/systems for refrigeration and lubrification,
- the survivability systems, i.e. the system allowing the WaveStar floaters to be risen up along the piles and the pressured-buoys system to submerge the floating DEXA in case of storms.

Maintenance: It is supposed that the main maintenance operations will be related to the anti-fouling and to the mooring system. However it is expected that the failure of a single chain will not compromise the wave farm efficiency if it is substituted in a short time.

If particularly strong storms occur it could be possible that devices/floaters will be damaged, and therefore they will be replaced. Device replacement will require the same operation considered for the installation phase, including the use of vessels.

Decommissioning: When decommissioning the site, the floating parts of the wave farm can be simply transported by vessel to the shore, where they can be dismantled. The concrete anchor blocks and the piles will of course remain in place at the installation site.

For the fixed installation the use of the structure, for example for a protected marine park, should be considered (as it happened with the sunken Paguro gas platform, http://it.wikipedia.org/wiki/Relitto_della_piattaforma_Paguro).

<u>For Power extraction and transfer</u>

Taking into account the distance to the shore and the potential size of MUPs/SUPs, from the energy point of view, the following key components will be installed, maintained and decommissioned:

- Export Cable – from offshore substation to shore (not present in stand alone configuration)
- Distribution cables – from each energy converter to the substation
- Offshore substation – where the distribution cables are collected and the voltage increased for minimizing export power losses or, in case of stand alone solution, electric loads are present and a storage system is installed

Export cable

Due to the expected size of the offshore farm, essentially based on wave energy plus a possible integration from the small wind turbines, and according to the distance to the shore amounting to a maximum of 35 km, according to figure --, a MVAC connection at 33 or 72kV is envisaged.

Cable protection is essential in order to avoid trenching or damage to the cables, mainly by inshore fishing activity and dragging anchors from coastal vessel traffic. As it can be expected, the export cable is much more exposed than distribution ones to this kind of damage.

Cables are therefore generally buried at a certain depth under the sea bottom or, as an alternative, cables can be laid on sea bottom and then protected by means of various techniques, like for example rock burial, concrete mattresses and sand bags.

Cable installation methods adopted to date have included simultaneous lay and burial, using a variety of subsea trenching and burial equipment deployed from both barges and Dynamic Position vessels. Post lay burial using special jetting or mechanical trenching tools is also possible the most correct method will depend on several factors, with the important remark that the cable must be type approved for the installation method to be used.

According to the desired burial depth and the geology and geomorphological characteristics of the sea bed (sandy, rocky, gravel), different burial machines can be used, like cable burial ploughs, burial sleds or even swimming ROVs with cable burial capability.

Also, even if not offshore specific, onshore works will be needed to provide onshore substation connection to the shore and export cable. Directional drilling might be needed in the transition between onshore and offshore area.
Decommissioning of buried sea cables is very likely to cause a relevant impact on the seabed and therefore cable might be left in its position at the end of the MUP lifetime. Otherwise, specific vessel tow under-running devices able to de-bury the installed cables.

Distribution cables
Distribution cables collect energy from all of the converters and bring it to a single point, which can be a simple collection point (junction box) or a substation with switchgear and voltage step up functions. Similar considerations about export cables can be done about installation and decommissioning.
In case of floating devices, dynamic cables are needed. In this case, a subsea wet mate connector is needed between the subsea dynamic cable and the static section.
In case of fixed structures distribution cables are generally buried in the seabed till wind turbine or platform base, then pass through a vertical tube from seabed to above water level, which is called J-tube or I-tube for its shape, by means of a pulling wire or pulling head: after a brief path in air it is constrained rigidly to the platform by an anchoring device called hang–off. J-tube/I-tube seals are used to prevent exchange of fluid within the tube with seawater. The remaining part of cable is then fixed to metallic structures called ladders before being terminated generally in an harsh environment: open air termination are possible only for moderate voltage levels. The cables are often terminated in encapsulated switchgear by Gas Insulated Switchgear terminations, polymeric plug-in connectors, transformer termination; all these components require particular protective treatments.

Offshore substation
The offshore substation has the function of collecting the power generated by the energy converters and stepping up voltage transmission level to shore and/or having switchgear capabilities if needed. It can be located both above or under the sea level and can be fixed to seafloor or floating.
It is normally located close to the centre of the offshore site to minimize array cable lengths. Offshore sub stations designs generally have until now comprised a complete topside module installed onto a piled jacket or mono-pile foundation. Their installation is normally carried out using a floating heavy lift crane barge, with transportation of the foundation and topsides also carried out by the installation barge or by using a dedicated transportation barge. Also self installing design have been proposed and may have a important role in the near future.
At the end of the project the substation decommissioning is envisaged.

3.5.3 **Risks**

Function	Risk
Fish farm	Structural Stability *Cable failure* Pollution *Fish feeding and increase of nutrients*
Wave farm	Structural Stability *Mooring failure* *Overloading on piles* *Scour at pile foundations* *Syphoning of foundations or anchors* Performance *Decrease of performance due to fouling on floating parts* Pollution *Debris caused by failure/degradation of floating parts* *Abrasion of the anti-fouling painting* *Spilling of fluids for refrigeration/lubrification*
Wind farm	Structural Stability *Overloading on piles* *Scour at pile foundations* *Syphoning of foundations* Pollution *Debris in case of micro-wind*

3.5.4 **Environmental impact assessment**

Habitat modifications

The construction of marine infrastructures, including MUPs, typically involves the replacement of natural, most often sedimentary, substrata with harder surfaces of stone, concrete, asphalt, metal or other artificial material. These habitat modifications altered the distribution of a number of species, which thrive on these anthropogenic surfaces. For this reason marine infrastructures are sometimes perceived as an opportunity for habitat enhancement, providing local benefits associated to hard substrata where none previously existed, or potential refugia for rare or threatened native rocky species (Inger et al. 2009, Martins et al. 2010, Sheehy and Vik 2010, Langhamer 2012, Perkol-Finkel et al. 2012). At the same time, the long-term and regional consequences of these extensive habitats modifications are debated (Airoldi et al. 2005a, Fauvelot et al. 2012, Witt et al. 2012). The ecological value as habitat of shorelines that have been altered to create new hard substrata can vary in relation to many structural and environmental factors (Moschella et al. 2005, Dugan et al. 2011). Also there is evidence that marine infrastructures can offer particularly favourable substrata to many non-indigenous species NIS (Bulleri and Airoldi 2005, Neill et al. 2006, Glasby et al. 2007, Vaselli et al. 2008, Dafforn et al. 2012, Mineur et al. 2012). NIS may colonize from nearby natural rocky habitats or could spread out of ports, harbours, marinas, or other sources of introduction.

When multiple artificial structures are built relatively close to one another, along stretches of coast comprising predominantly soft sediments, these structures can sometimes function as pathways or stepping stones, facilitating the spread and connectivity of both native and non-native marine species (Moschella et al. 2005). It is worth noting, however, that resistance of a community to the establishment of non-native species may increase with higher native species diversity (Stachowicz et al. 2002), especially if certain functional groups are present (Arenas et al. 2006). The risk of facilitating the spread of non-native species through the construction of artificial hard structures may thus be minimised through the incorporation of a variety of habitat features into the structure, if successfully colonised by a diverse biological community.

These issues are particularly relevant in the Adriatic Sea due to the large abundance of marine infrastructures. In the region exploitation of gas reservoirs began in the 1960s, and more than 100 platforms have been installed since then. The shape and the size of the platforms are variable, mostly depending on the depth of the sea bed at which the structures lay. In order to resist to different oceanographic conditions, structures range from monopods to multi-legs with the former mostly concentrated at shallow depth. Produced water is the major discharged effluent, and eco-toxicological studies have found no major pollution effects from the activity of gas extraction (Gorbi et al. 2008).

The sandy coastline is also highly urbanized (Cencini 1998). Along this entirely sedimentary coastlines, a variety of hard artificial structures have been built in the past 50 years, for harbours, ports and marinas and for protection of the coast, comprising > 100 km of groynes and breakwaters, > 60 km of seawalls and > 40 km of jetties (Cencini 1998, Bacchiocchi and Airoldi 2003). Previous work has documented the prevalence of assemblages characterized by low species and genetic diversity on these structures (Bacchiocchi and Airoldi 2003, Fauvelot et al. 2009), which favour flora and fauna that often represent an early stage of succession, comprising opportunistic and invasive species (Bulleri and Airoldi 2005). This has generally been attributed to the high levels of disturbance in these environments (Airoldi et al. 2005b, Airoldi and Bulleri 2011), although the prevalence of non-indigenous species in these systems has not been analysed in a broader regional context.

Overall the northern Adriatic Sea can be considered a hotspot of species invasions. In particular, the Lagoon of Venice in the northern Adriatic Sea, with its crowded recreational and commercial harbours, as well as a flourishing mariculture activity, is the Italian locality with the highest number of marine aliens (Figure 3.5.13): 39 species, including 12 algae, 9 molluscs, and 9 crustaceans (Occhipinti-Ambrogi et al. 2011).

Other processes could also contribute to shape benthic assemblages in the region, either amplifying or masking the effects of offshore platforms. For example, in the North Adriatic sea commercial trawling is intensive (Pranovi et al. 2000), and the system is considered to have entered a "fished state" sensu Jennings and Kaiser (1998), where additional disturbances may no longer lead to clear responses in assemblage structure. Offshore structures provide some degree of refuge from trawling activities (De Biasi and Pacciardi 2008, Terlizzi et al. 2008) as for safety reasons it is forbidden to navigate closer than a distance of between 200m and 1000m from offshore platforms (Art. 28 del D.P.R. 886/79). Trawling is known to modify deep benthic systems, causing reduced species' abundances and changes in species composition, with an increase in deposit feeders and a decrease in suspension feeders with increasing fishing pressure (Thrush et al. 1998). The effects of trawling tend to be particularly evident in homogeneous sediment types that are usually less affected by natural physical disturbances (Kaiser and Spencer 1996).

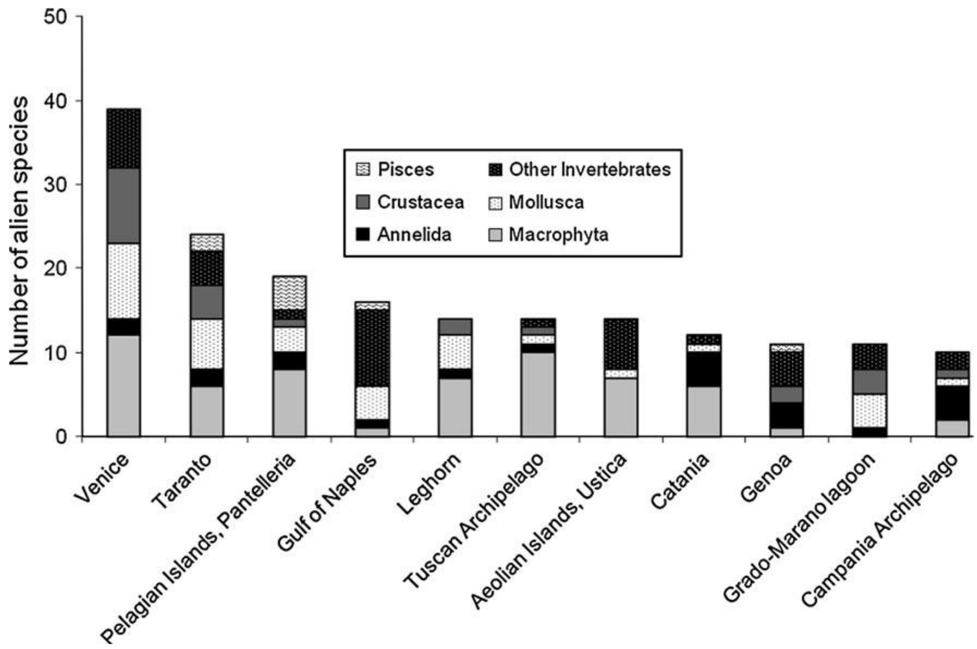


Figure 3.5.13 - Number of alien species recorded in the hotspots of introduction along the Italian coast (Occhipinti-Ambrogi et al. 2010).

Fish farming

Experimental work carried out in the Mediterranean on the environmental impact of fish farming of sea bass and sea bream has shown that this can vary greatly depending on the hydrography of the site stocking density, on the feed type etc and that the effects can be significantly reduced by careful site selection, control of stock density, improved feed formulation and integrated culture with macroalgae, filter-feeders and deposit-feeders (Borja et al 2009, Keleey et al 2013).

Some of the most important effects that have been documented concern increase in organic matter contents and compositional changes of the sediment below fish cages, alteration of inorganic and organic chemistry of farm water and sediments, alteration of abundance, biomass and biodiversity of micro, meio and macro benthic communities and modification of distributional patterns of phyto and microplankton abundance and production (Sarà et al 2004, 2011, Pusceddu et al 2007, Aubin et al 2009, Luna et al 2013, Martinez-Garcia et al 2013). Although large scale modification of the trophic status (i.e. nutrient concentrations and phytoplankton biomass) of marine areas have been described as a consequence of fish farming (Aubin et al 2009, Sarà et al 2011), most of the described impact are normally confined to within 25 m (Karakassis et al 1998), 20-50m (Beveridge 1996) and 84m of the farm (Forchino et al 2011), and no effects can be detected at a distance of ~1km (Forchino et al 2011).

Specifically, long term studies at fish farming sites where all operations were conducted in accordance to the legislative specifications and the code of conduct for responsible development of aquaculture, did not show any clear evidence of irreversible damage caused to the environment around and under the sea cages (Karakassis et al 1998, 2000, 2002, 2005, Klaoudatos et al 2006). Furthermore, at a distance of 25m or further away from the sea cages, no impacts could be traced on the sea bed (Karakassis et al 1998). It is therefore recommended that all aquaculture operations are carried out according to the relevant legislations and the method of fallowing is applied (periodic rotation of the site of cage parks every 3-5 years, so that the seabed underneath the cages is left to recover), as it has been show that these practices can significantly mitigate the environmental impacts.

Wave farm

One of the most relevant issues affecting the environment is represented by the abrasion/crack of the anti-fouling painting, which is pretty toxic but is needed for the floating parts of the devices.
The presence of piles, scour protection at piles, and anchors affects the soft bottom assemblages and increases habitat biodiversity, however it should not change the habitat at the seabed at large scale and it should also not increase the spreading of invasive species. The scour protection at the piles in case of the fixed farm and the anchors for the floating farm might also attract valuable species.
The number of floating DEXA devices may produce a significant change of light along the water column and therefore affect water oxygenation.
The failure of part of the floating structures may affect the fauna, therefore the shape of the floaters should be optimized to minimize the risk.
The wave farm produces a limited local impact a) on hydrodynamics: wake effects are not supposed to produce major changes due to the modest wave absorption (around 70% wave transmission behind the farm); b) on morphology: there is no risk of induced breaking or increased currents, and therefore an increased sediment suspension is essentially expected only during the construction phase.
Since the wave farm is placed in deep water, the impact on the coast due to the modest variation of sediment transport patterns induced by wave reduction and change of wave direction will be also very limited.
The acoustic impact of the wave farm should be very limited, and therefore it is not supposed to annoy the local fauna.
The visual impact is of course more relevant in case of a fixed installation.

Design options to mitigate the spread of non-indigenous species

Because the North Adriatic Sea is a hotspot of species invasions, particular attention should be devoted to identify designs and methods to mitigate their spread. There are several options that could help reduce the likelihood of establishment of invasive non-native species on marine energy infrastructures and that are related to both the installation, operation and maintenance phase (Airoldi and Bulleri 2011, Dafforn et al 2012, Langhamer 2012, Firth et al submitted,). These options are applicable to any type of marine infrastructure, no matter whether wave or wind energy:

- Avoid building structures in close proximity to harbours or shipping routes as this may increase the likelihood for those structures to become colonised by invasive non-native species;
- Consider that proliferation of structures (energy parks) will increase connectivity in the system, potentially favouring the dispersal of some native but also non-native marine species, via stepping stones. For the north Adriatic sea this could represent an important issue, as the area is a hotspot of species invasions;
- Consider that floating and sheltered surfaces are more prone to invasions by non-indigenous species than fixed and exposed surfaces;
- In general, limit disturbances (from i.e. maintenance, or harvesting), as they will cause a significant enhancement of opportunistic and invasive forms, such as biofilms, opportunistic and/or non-indigenous species.
- If interventions are needed, plan and schedule the interventions based on ecological knowledge of the systems, as this can help reduce some of their negative impacts

- Apply principles of ecological engineering for encouraging biogenic build-up, thus reducing the frequency/magnitude of maintenance works in the long run.

One option to test for the North Adriatic is to encourage native biogenic buildup. Currently we are testing techniques to promote resilient, native communities dominated by canopy-algae (fucoids belonging to the genus *Cystoseira*) on MUPs. Such gardening of canopy-forming algae is not expected to have any negative effect on the performance of the structure, while limiting some impacts (e.g. reduced likelihood of spread of alien species, improving water quality, enhancing primary productivity, providing valuable biogenic habitat). Depending on the depth and local environmental conditions (particularly turbidity) such macroalgal growth could also contribute to mitigate scouring around wind power pilings

There are several transplantation techniques that have been suggested to work for artificial enhancement of fucoid algae typical of the Mediterranean sea. *Cystoseira* has been transplanted experimentally using several techniques: plants were tethered for few days to other macrophytes using plastic cable ties (Verges et al. 2009), entangled in a plastic net screwed in the rock for two months (Wallenstein et al. 2009), attached with a nylon line to a plastic mesh fixed to a ceramic plates for one month(Hereu 2006), fastened to bricks with polyurethane foam for one year (Falace and Bressan 2006) and fixed with epoxy putty, both detaching pieces of rocks bearing adult individuals for 9 month (Sales et al, 2011) and directly in holes drilled in the rocks for more than one year (Mangialajo et al. 2012). Larger scale transplantation efforts have also been attempted (Falace et al. 2006, Perkol-Finkel and Airoldi 2010, Perkol-Finkel et al. 2012).

3.5.5 **Socio-economic impact**

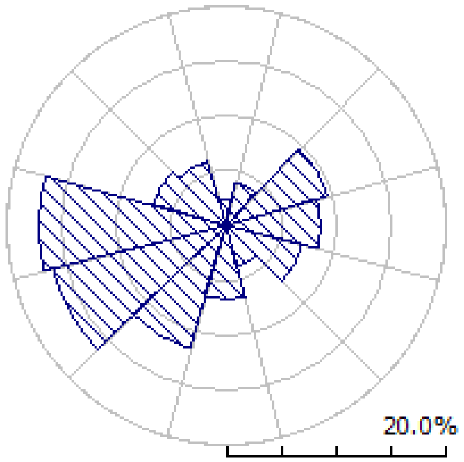
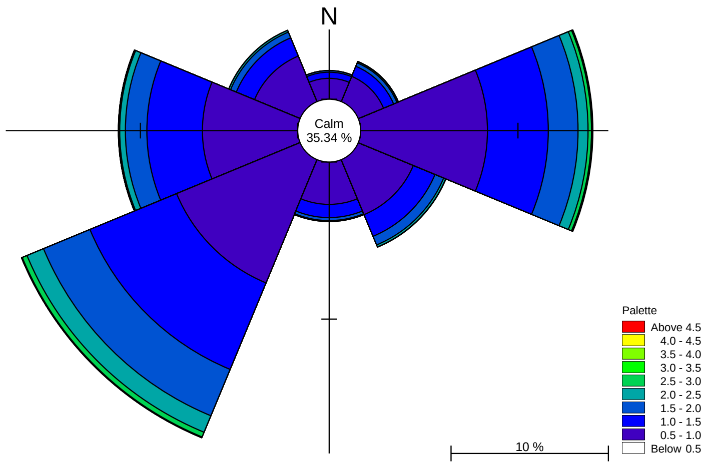
A specific Input-Output analysis will be applied to alternative combinations of uses (i.e. wave, fish, wave and fish, wave and fish and wind) in order to identify the direct and indirect economic and social impacts. Indeed, an Input-Output analysis is a methodology which takes into account inter-industry sales and purchases of intermediate inputs in order to measure the impact of an increase in final demand expenditure (e.g., due to the development of a new project) on the level of output and employment of each industry. Note that the linear relationships between sectors are reasonable in our context, due to the relatively small economic and social sizes of our project with respect to the regional GDP and employment levels. In particular, a preliminary Input-Output analysis for a wave - fish - wind MUP, where annuities of investment costs are calculated for a 30 years period and at a 2% discount rate, shows that, although direct net benefits are quite small (i.e. 400,406 euros per year), remarkable direct and indirect economic impacts (i.e. income) and social impacts (i.e. employment) are expected at regional level (Table 3.5.9): an increase of 0.03% GDP and an increase of 0.22% employment. THESE REUSLTS ARE EXPLANATORY ONLY. Note that some economic activities must be combined to make MERMAID data be consistent with Italian National Statistics.

Table 3.5.9 - GDP (Million euros) and employment direct and indirect impacts based on annual simulated costs (Million euros).

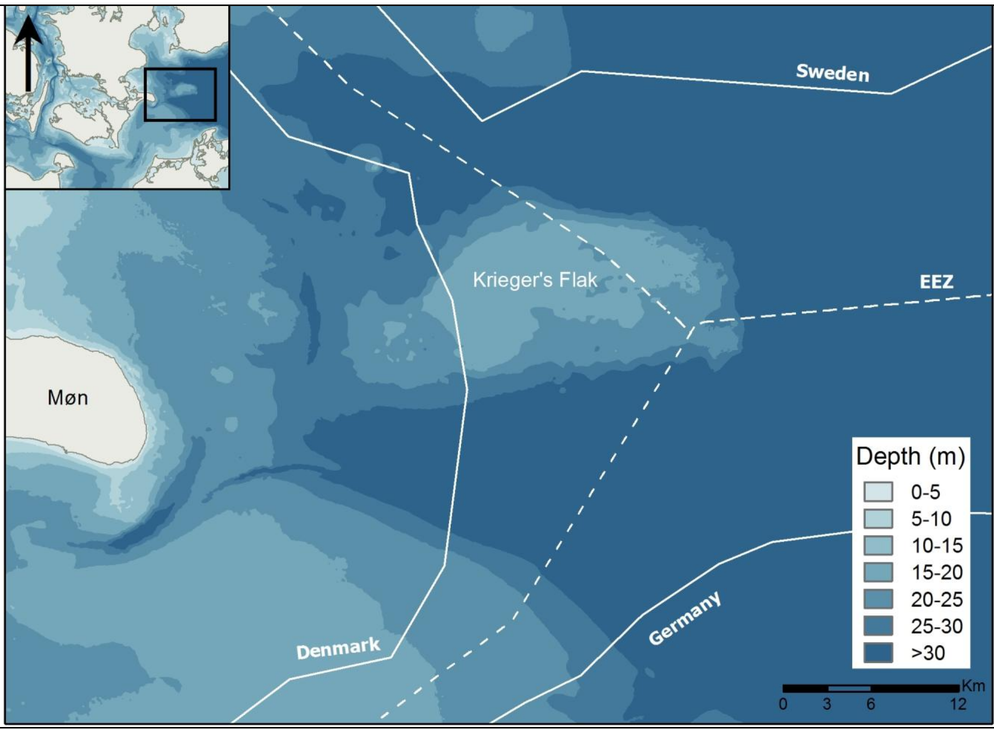
Economic activities	Simulated costs	GDP impact	Employment impacts
Agriculture, Forestry	0	0.364	87
Fishing	5	5.046	798
Energy Mining	0	1.200	918
Non-energy Mining	0	0.162	20
Food, drink and tabacco manufacturing	0	0.726	46
Fabric and clothes manufacturing	0	0.401	21
Leather manufacturing	0	0.115	4
Wood manufacturing	0	0.273	23
Paper manufacturing	0	0.605	51
Oil manufacturing	0	1.144	60
Chemical manufacturing	0.5	2.926	208
Plastic and rubber manufacturing	2	2.856	215
Non metal manufacturing	0	0.436	45
Metal manufacturing	1	6.055	504
Mechanical tools	0.5	6.176	320
Electircal and optical tools	1	2.304	135
Transport tools	0.5	1.273	90
Other manufacturing	0	0.415	22
Electricity, Gas and Water Supply	0	1.420	186
Construction	0	0.325	19
Wholesale & Retail Trade	0	0.697	44
Accommodation, Cafes and Restaurants	0.5	0.792	65
Transport and Storage	0.5	1.556	261
Finance and Insurance	0	1.050	46
Property and Business Services	0.5	3.766	805
Government Administration and Defence	0	0.006	1
Education	0	0.040	1
Health and Community Services	0	0.008	0
Cultural and Recreational Services	0	0.311	34
Personal and Other Services	0	0.000	0
TOTAL IMPACTS	16.5	42.449	5030

4 Overview of the site conditions and of the preliminary design

4.1 Estuarine site, Baltic Sea

Site	
Location	55° 0'11.44"N, 13° 4'45.27"E
Wind climate	
Typical range (mean and std) V, MWD	W to WSW - Wind rose 
Extreme conditions (Tr=100 years) V, MWD	
Expected annual wind power	297 W/m^2
…..	
Wave climate	
Typical range (mean and std) Hs, Tp	Mean Hm0: 0.8 m, Mean period: 3.5 s Wave rose at Kriegers Flak 

Extreme conditions (Tr=100 years) Hs, Tp	5.5 m 4.5 s
Expected annual wave power	none
…..	
Tidal range	
Typical range (mean and std) Z, V	Non-tidal
Exceptional annual Z, V	Maximum surge: 2 m
Expected annual tidal power	0
…..	
Water characteristic parameters	
Salinity, typical range (mean and std)	7-8 psu, variation between 5 to 20 PSU
Temperature, typical range (mean and std)	0-18 celcius
Nutrients, typical range (mean and std)	Tot P: 1 µM, tot-N: 25 µM
…….	
Policies and regulations	
EC directives	Future framework for “Maritime Spatial Planning and Integrated Coastal Management” (*areas should be allocated for energy production and aquaculture*)
National laws	Danish legislation as consolidated act. No. 932 issued April 24th 2009 (*nutrient emission should be reduced*)
HelCom	HelCom plans to reduce nitrogen loading to the Baltic Sea by 35%
Conflict of use	
Protected areas	No protected areas within 30 nm
Protected species	No protected species
Maritime routes	No regular routes
…..	

Platform area	
Image of the area interested by the platform in the site	
Long-shore x cross-shore extension, m	10 km x 10 km
Installation depth range, m	28 m
…..	
Design of the platform	
Energy conversion	Wind Y Wave N Tide N
Aquaculture	Y
Mariculture	Y
Seaweed farming	Y
Fish farming	Y
…..	
Scheme of the preliminary design	Wind turbines and aquaculture
Type of structures	Jacket or gravity based turbines, moored aquaculture cages
Transport demand	30 km

4.2 Active morphology site, North Sea and Wadden Sea

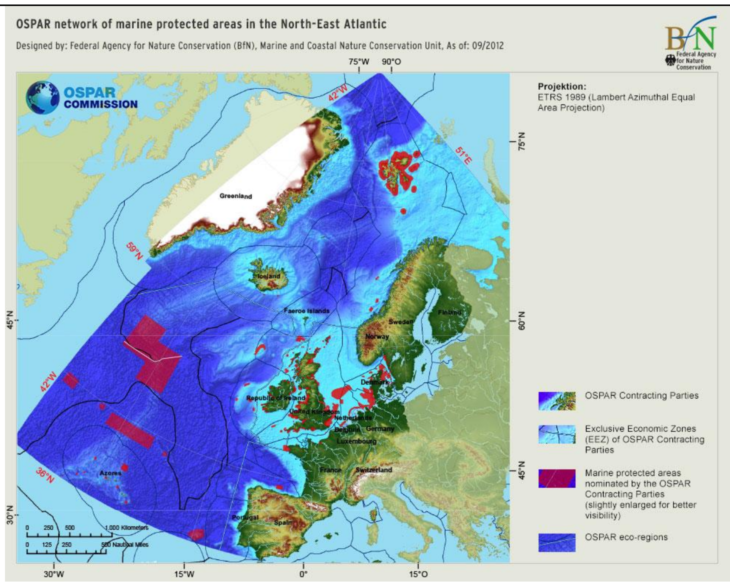
Site	Gemini wind park, The Netherlands
Location	54.036° latitude, 5.96°longitude
Wind climate	
Typical range (mean and std) V, MWD	
Extreme conditions (Tr=50 years) V, MWD	25.7(m/s) (extreme sea state)
Expected annual wind power	
…..	
Wave climate	
Typical range (mean and std) Hs, Tp	

$Wind_{10m}$ [m/s]	H_s [m]	T_p [s]	Spectrum [-]	Gamma γ [-]	duration [%]
< 4	0.7	7.4	Jonswap	1.44	14.4
4 - 5	0.9	7.0	Jonswap	1.44	8.6
5 - 6	1.0	6.8	Jonswap	1.44	9.8
6 - 7	1.1	6.6	Jonswap	1.44	10.6
7 - 8	1.3	6.5	Jonswap	1.44	10.4
8 - 9	1.5	6.5	Jonswap	1.44	9.4
9 - 10	1.7	6.8	Jonswap	1.44	8.2
10 - 11	2.0	7.0	Jonswap	1.44	7.0
11 - 12	2.3	7.3	Jonswap	1.44	5.6
12 - 13	2.6	7.6	Jonswap	1.44	4.4
13 - 14	3.0	7.9	Jonswap	1.44	3.5
14 - 15	3.3	8.2	Jonswap	1.44	2.6
15 - 16	3.7	8.6	Jonswap	1.44	1.8
16 - 17	4.1	9.0	Jonswap	1.44	1.3
17 - 18	4.6	9.5	Jonswap	1.44	0.9
18 - 19	5.0	9.8	Jonswap	1.44	0.5
19 - 20	5.5	10.2	Jonswap	1.44	0.3
20 - 21	6.1	10.8	Jonswap	1.44	0.2
21 - 22	6.5	11.1	Jonswap	1.44	0.1
22 - 23	7.0	11.5	Jonswap	1.44	0.1
23 - 24	7.4	11.8	Jonswap	1.44	0.0
24 - 25	7.6	11.5	Jonswap	1.44	0.0
25 – 26	7.8	11.1	Jonswap	1.44	0.0
> 26	8.4	11.3	Jonswap	1.44	0.0

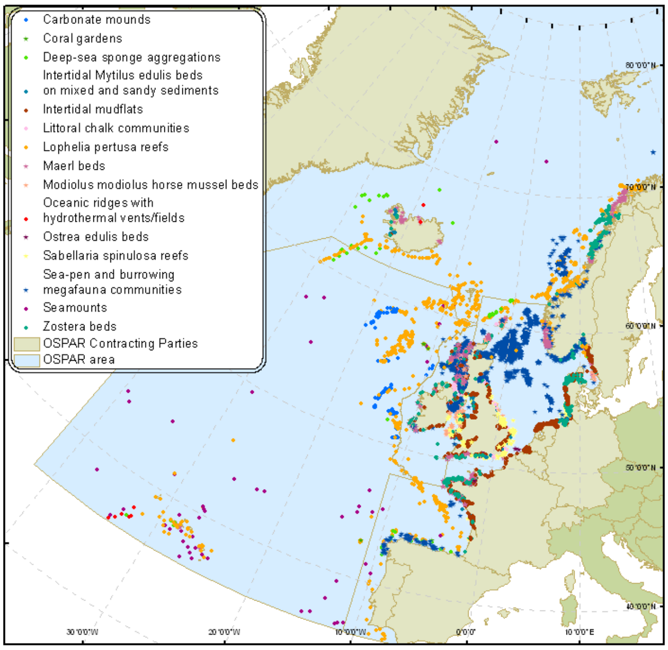
Extreme conditions (Tr=50 years) Hs, Tp	Hs = 11.2(m) Tp=16(s)
Expected annual wave power	10~15kW/m
…..	
Tidal range	
Typical range (mean and std) Z, V	

Astronomical tidal level	Level [m, MSL]
Highest Astronomical Tide	0.95
Mean High Water Spring	0.65
Mean High Water Neap	0.45
Mean Sea Level	0.00
Mean Low Water Neap	-0.45
Mean Low Water Spring	-0.75
Lowest Astronomical Tide	-1.00

Exceptional annual Z, V	
Expected annual tidal power	
…..	
Water characteristic parameters	
Salinity, typical range (mean and std)	The salinity mainly varies between 32.5 and 35 ppt
Temperature, typical range (mean and std)	The sea temperature varies between 2 °C and 20 °C

<table>
<tr><td>Nutrients, typical range (mean and std) (Source: Digital Atlas of the North Sea 2009)</td><td>
<table>
<tr><th>Nutrients bottom water column</th><th>Min</th><th>Max</th><th>Mean</th><th>std</th></tr>
<tr><td>Nitrate winter (µmol/l)</td><td>0.1</td><td>476.6</td><td>11.9</td><td>18.5</td></tr>
<tr><td>Nitrate summer (µmol/l)</td><td>0.01</td><td>00.7</td><td>5.4</td><td>9.5</td></tr>
<tr><td>Phosphate winter (µmol/l)</td><td>0.01</td><td>8.2</td><td>0.7</td><td>0.4</td></tr>
<tr><td>Phosphate summer (µmol/l)</td><td>0.0</td><td>23.7</td><td>1.0</td><td>.4</td></tr>
<tr><td>Ammonium winter (µmol/l)</td><td>0.01</td><td>55.0</td><td>2.1</td><td>3.5</td></tr>
</table>
</td></tr>
<tr><td>…….</td><td></td></tr>
<tr><td>Policies and regulations</td><td></td></tr>
<tr><td>EC directives</td><td></td></tr>
<tr><td>National laws</td><td></td></tr>
<tr><td>…..</td><td></td></tr>
<tr><td>Conflict of use</td><td></td></tr>
<tr><td>Protected areas (Image of these areas in the site)</td><td>


http://www.bfn.de/habitatmare/en/karte-schutzgebiete-ospar.php
</td></tr>
</table>

<table>
<tr>
<td>Protected species
(Image of the areas where these species are present)</td>
<td>


http://jncc.defra.gov.uk/page-1583
OSPAR List of Threatened and/or Declining Species and Habitats:
http://www.ospar.org/content/content.asp?menu=00730302240000_000000_000000
</td>
</tr>
<tr>
<td>Maritime routes
(Image of these routes in the site)</td>
<td>

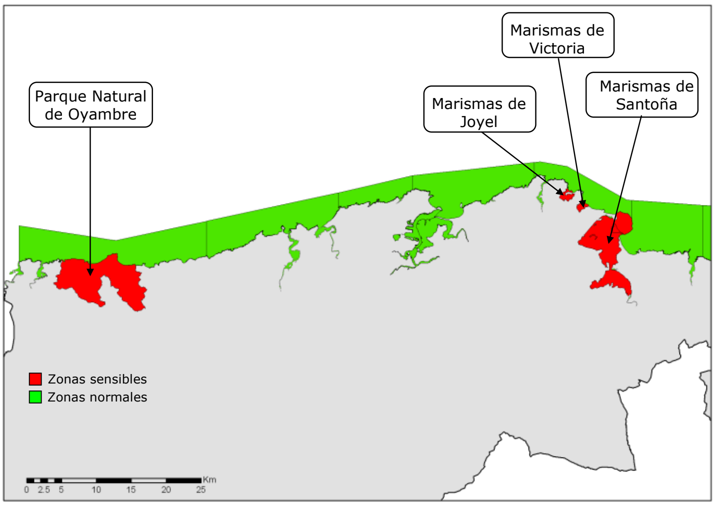

http://www.ecomare.nl/en/ecomare-encyclopedie/man-and-the-environment/shipping/shipping-routes/

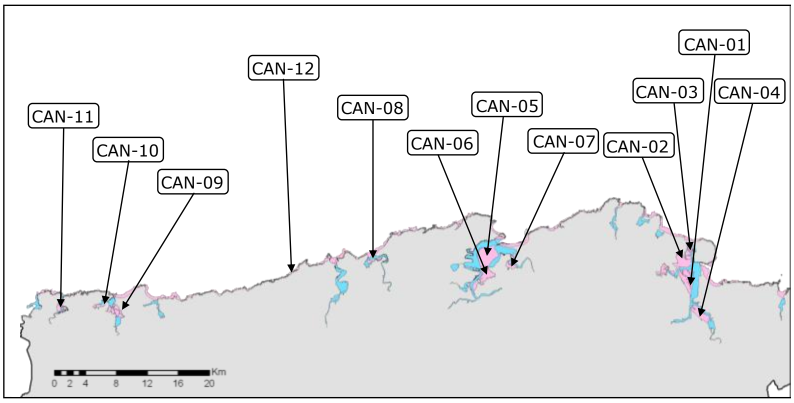
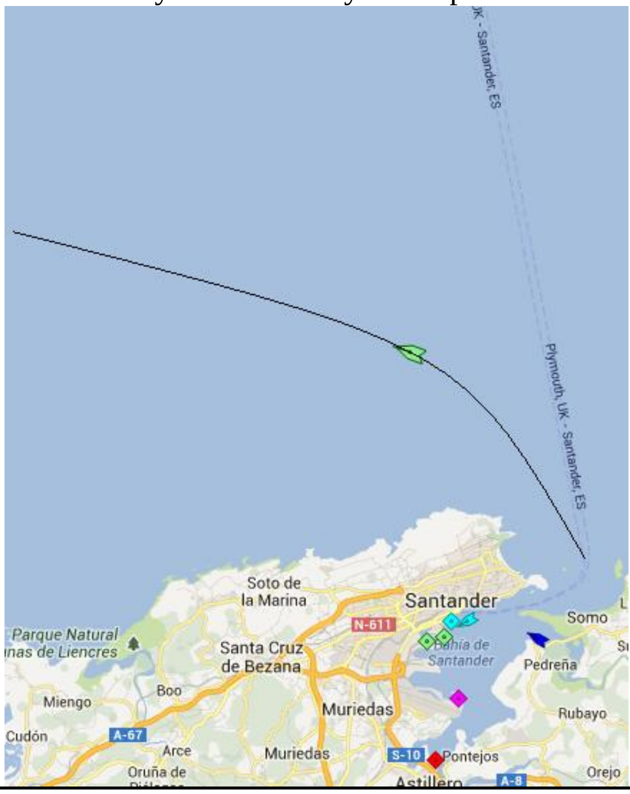
Dutch North Sea shipping routes will change as of August 1, 2013:
http://www.rya.org.uk/newsevents/news/Pages/NewNorthSeashippingroutes.aspx
</td>
</tr>
</table>

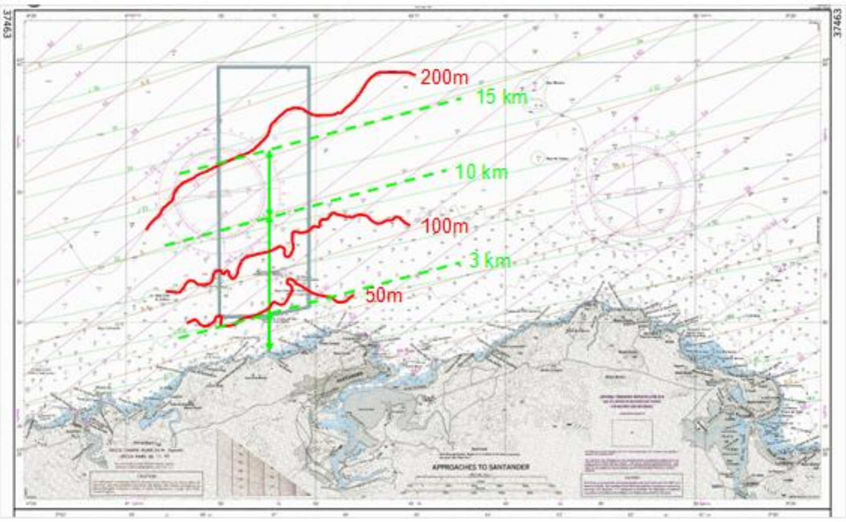
Platform area	
Image of the area interested by the platform in the site	
Long-shore x cross-shore extension, m	
Installation depth range, m	Water depth is between 28~35m
Design of the platform	
Energy conversion	Wind Y Wave maybe Tide N
Aquaculture	Y
Mariculture	Y mussle seed collectors
Seaweed farming	Y
Fish farming	Y (not yet, near future possibly)
Scheme of the preliminary design	
Type of structures	
Transport demand	
…..	

4.3 Open deep water site, Atlantic Ocean

Site	Open deep water site. Atlantic Ocean. Cantabrian Offshore Site (COS)
Location	Lon: 3.88ºW, Lat: 43.56N
Wind climate	
Typical range (mean and std) V, MWD	V: Min: 0 m/s Max: 27.85 m/s Mean: 6.11 m/s Std: 3.51 m/s
Extreme conditions (Tr=100 years) V, MWD	V: 27 m/s
Expected annual wind power	100.6133 MW/m2
…..	
Wave climate	
Typical range (mean and std) Hs, Tp	Hs: Min: 0 m Max: 12.0 m Mean: 1.98m Std: 1.32 m Tp: - Min: 2.8 s Max: 19.6 s Mean: 9.7 s Std: 2.66 s
Extreme conditions (Tr=100 years) Hs, Tp	Hs: 11m Tp:18s
Expected annual wave power	32.7 kW/m
…..	
Tidal range	
Typical range (mean and std) Z, V	Mean tidal velocity: 0.01 m/s
Exceptional annual Z, V	Maximum tidal velocity: 0.15m/s
Expected annual tidal power	<0,1W/m2
…..	

Water characteristic parameters	
Salinity, typical range (mean and std)	Salinity: Typical range: 33-36 PSU
Temperature, typical range (mean and std)	Temperature (ºK): Min: 284.05^0 Max: 297.92^0 Mean: 289.17^0 Std: 3.27^0
Nutrients, typical range (mean and std)	Nutrients: Oxigen: 6,5-8,5 mg/L
…….	
Policies and regulations	
EC directives	
National laws	Renewable Energies Plan 2011-2020 (PER) Renewable energies moratorium: New power plants developments Royal Decree No. 661/2007 Royal Decree No. 1028/2007
…..	
Conflict of use	
Protected areas (Image of these areas in the site)	No protected areas 

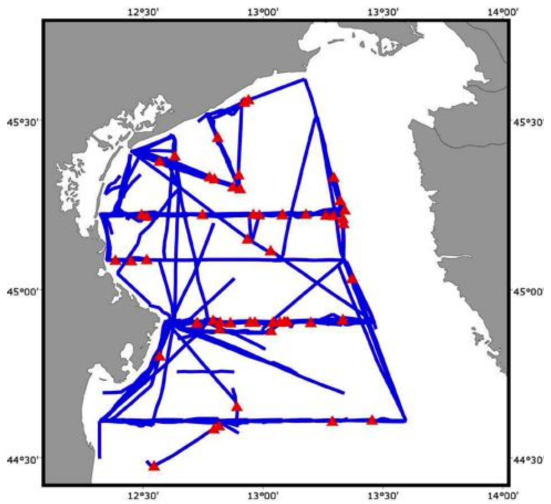
Protected species (Image of the areas where these species are present)	No protected species in the area 
Maritime routes (Image of these routes in the site)	No principal maritime routes in the site: - Cargo transport crosses the south of the area - Ferry Santander-Plymouth passes near the area 

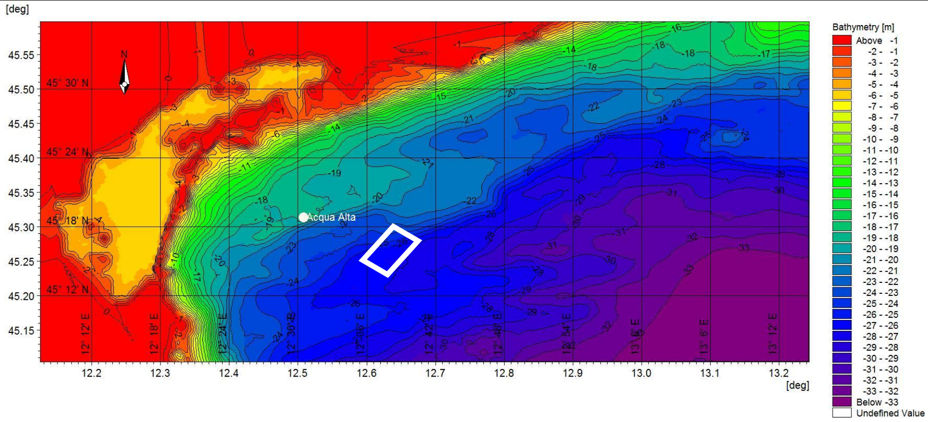
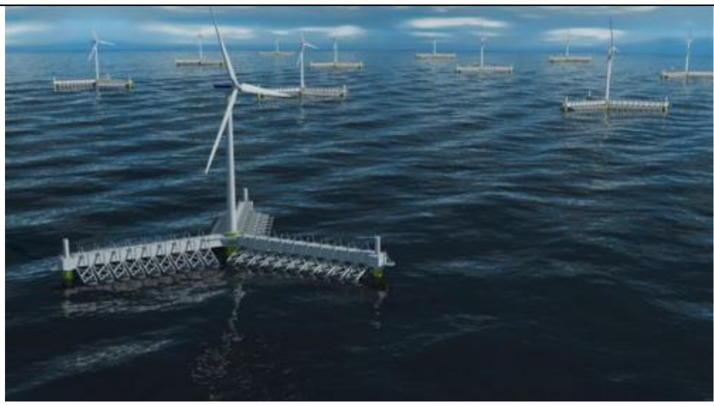
Platform area	
Image of the area interested by the platform in the site	
Long-shore x cross-shore extension, m	15 km x 5 km
Installation depth range, m	50 – 200 m

Design of the platform	
Energy conversion	Wind Y N Wave Y N Tide Y N
Aquaculture	Y N
Mariculture	Y N
Seaweed farming	Y N
Fish farming	Y N
…..	
Scheme of the preliminary design	
Type of structures	Semi-submergible based offshore wind turbine and ship-shaped wave energy converter
Transport demand	Tug boats

4.4 Deep sheltered site, Mediterranean Sea

Site	Off-shore Venice
Location	latitude: 45 deg 18 min 51 sec North; longitude: 12 deg 30 min 30 sec East.
Wind climate	
Typical range (mean and std) V, MWD	4.54 m/s, 40°(+/-20°) and 120° (+/-20°)
Extreme conditions (Tr=100 years) V, MWD	28.08 m/s, 40°(+/-20°)
Expected annual wind power	Large wind: 12.7 GWh/y / 4 turbines Vestas V112
Wave climate	
Typical range (mean and std) Hs, Tp, MWD	1.25 m, 5.5 s, 45°(+/-30°) and 130° (+/-30°)
Extreme conditions (Tr=100 years) Hs, Tp, MWD	3.99 m, 8.5 s, 70°(+/-20°)
Expected annual wave power	3 kW/m
Tidal range	
Typical range (mean and std) Z, V	0.5 m (+/-0.15 m)
Exceptional annual Z, V	0.85 m
Expected annual tidal power	-
Water characteristic parameters (at 15 m depth)	
Salinity, typical range (mean and std)	27.5 psu (+/-1.5 psu)
Temperature, typical range (mean and std)	14°C(+/-6°C)
Nutrients, typical range (mean and std)	2 mmol l^{-1}(+/-1 mmol l^{-1})
Policies and regulations	
EC directives/regulations	Fishery EU Regulation No.1263 of 1999 EU Regulation No.2792 of 1999

National laws	Use of marine space National Legislative Decree No. 112 of 1998 Regional Law No.11 of 2001 Fishery Legislative Decree No.154 of 2004, Art. 12 Legislative Decree No.11954 of 2010, Art. 4 Legislative Decree No. 4 of 2012, Art.7 Energy Circular Letter No. 40 of 2012 by the General Direction of the Ministry of Infrastructures and Transports Legislative Decree No. 28 of 2011
Conflict of use	
Protected areas	-
Protected species	 Routes travelled and sightings of *Tursiops truncates* during 2003-2006  Distribution of loggerhead turtles in the Mediterranean Sea
Maritime routes	-

Platform area	
Image of the area interested by the platform in the site	
Long-shore x cross-shore extension, m	~1200 m x 800 m
Installation depth range, m	20-35 m
Design of the platform	• Floating wave energy farm • Fixed wave energy devices on piles
Energy conversion	Wind Y Wave Y Tide N
Fish farming	Y
Mussel farming	Y
Scheme of the preliminary design	 

Type of structures	Two solutions are essentially under exam (considering wave energy the leading purpose of the platform): • Floating wave energy devices (DEXA) • Fixed system on piles (WaevStar) with floaters These two different structures can then be combined with • Large wind (monopole turbines) • Micro-wind (tilt-tower on the platform of WaveStar only) • Sea cages and cables for fish farming or for mussel farm
Transport demand	Normal vessels required for maintenance and transportation Distance from shore can be covered in about 1h30’ Periodic maintenance at least once/month in case fish farming is pursued

5 Conclusions

5.1 Baltic Sea

The advance status and way ahead for the development of the multi-use platform at Kriegers Flak in the Baltic Sea can be summarized as follows.

- The expectations from the stakeholders within the wind turbine industry are that increased risks should be avoided, e.g. from navigation or direct impact from floating cages. The possible synergies may be in the better utilization of the reserved areas and more efficient operation and maintenance. From the aquaculture end users the possible availability of offshore sites for fish production is seen as valuable, but also the common O&M infrastructure is positive.
- The energy concept for the Baltic site will be wind turbines using either gravity based foundations or jacket structures
- The EIA will need to consider the impacts from construction of the turbine foundations, the fish farming facilities and the cable laying. During operations both turbines and farms will require access which may have an impact on energy balances and on areal use in the area. For the aquaculture activities, impact from fish growth on water quality in the local area and in the greater Baltic as well as spreading of diseases must be considered
- The impact on seabed from placement of fixed structures is considered. This will involve estimates of relevant seabed protection schemes as well as estimates of possible scour depths.
- When a first draft of the final design has been developed, its suitability with respect to transportation to site and the installation will be considered. This will involve recommendations for suitable equipment and procedures for turbine foundations, turbines, fish cages and anchoring, possible substation and aquaculture production units, crew housing. Also the installation of local cabling and grid connection to shore will be addressed.
- A safe and sustainable decommissioning will also need to be included in the design analysis, avoiding non-recyclable or not sustainable materials and procedures
- To develop a proficient decision base a cost-benefit analysis based on the monetary value of the socio-economic impact of both the single use platform case and the developed multi-use platform case will be developed. The analysis will be based on data produced in the workpackages, but will rely especially on the workpackages WP 2, WP4 and 5 and WP 6.

5.2 North Sea

The exact location of the North Sea site is well-known and more details can be found on the website: www.4coffshore.com/wind_farms/gemini-netherlands. The granted Gemini wind farm concession and permit are only for single use activities. The MUP possibilities are just conceptually based land fully under discussion. Since half a year many Dutch stakeholders are increasingly interested in more multi-use activities. Especially the wind-user group is very clear in the technical MUP requirements:

- no hindrance of wind turbines
- no obstacle in case of operational and maintenance activities (O&M)
- preferably modular components and plug and play installations in case of multi-use activities

Besides they are more interested in making use of the same infrastructure for reducing their O&M costs. Also the end-user group for offshore aquaculture and fisheries are becoming in favour of sharing infrastructures, on the one hand to lower their O&M costs while on the other hand to earn more money by multipurpose activities. From the investors point of view minimal impact (risks) is required in developing single- up to muli-use activities in/near the same area as the wind farms.

For offshore aquaculture activities still many technical and biological requirements are still unknown. Before organizing the actual MUP workshop many stakeholders require site-made concepts before deciding to further participate in the MERMAID project. Also they want to who else is taking part in further developing this North Sea site-case. For the northern region with much unemployment every action to increase the employment possibilities is more than welcome. Especially the local fishermen (organizations) are very interested in additional work for their fishing vessels. However the technical requirements for these existing fishing boats must be reconsidered as well as the operational possibly risks, so that they can get a license to produce in or near the wind farms.

5.3 Atlantic Ocean

The advance status of the data collection and of the preliminary design in each site it is summarized as follows:

- Design expectations from end users and design suggestions by scientists (WP2):
    - Information from stakeholders have already included.
    - Next rounds of interviews and round tables will be included on next steps
- Identification of promising energy concept to be integrated in the design (WP3):
    - Metocean data assessments at the site have been already include, including design conditions as well as energy availability.
- Steps and data needed for EIA (WP4):
    - A detailed EIA will be included when the final design will reach a more mature level
- Hydrodynamics and morphological maps to estimate the impact of the platform (WP5)
    - A detailed Hydrodynamics and morphological maps will be included when the final design will reach a more mature level.
- Optimization of the design accounting for the transportation, installation, decommissioning (WP 6):
    - The optimization of the transportation, installation, decommissioning design will be included when the final design will reach a more mature level.
- Steps and data needed for cost-benefit analysis in case of single and multi-use platform (WP 8)
    - The information need by the cost-benefit analysis is under generation, at the end of the project will be available detailed information needed.

5.4 Mediterranean Sea

The area off-shore Venice is characterized by a relatively mild climate that allows in principle a safe installation of an off-shore platform but at the same time strongly limits the benefits of a single–purpose installation, both because of the limited available energy and because of the high distance from the shore due to the flat sea-bottom.

Therefore the site is particularly suited for multi-purpose design, which based on this preliminary analysis of constraints and feasibility will consider

- extraction of power from waves, either through a fixed or a floating installation adopting WaveStar or Dexa devices respectively; the annual wave energy production is rather limited due to the limited device efficiency, and therefore a minimum marine space of 1 km^2 is required;
- extraction of power from wind; since the available annual resources is very limited, this function will be designed only in combination with the wave farm,
  - by means of micro-wind systems placed on top of the fixed WaveStar arms and/or of large wind turbines on top of the piles supporting the WaveStar installation;
  - by placing few large turbines at the boundaries of the Dexa floating farm;
- fish farming, through the development of a combined design with the wave farm installation in order to optimize the use of the cables and of the moorings;
- transfer to shore and standing-alone solutions; the latter is particularly promising due to the relatively high distance from shore if the energy is essentially used for the needs of the fish, wind and wave farms and the remaining energy is locally stored.

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